

Influence of Environmental Factors on Asthma

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Abstract - The severity of asthma has been discerned to be influenced by environmental factors such as air pollutants and meteorological factors. With this chronic respiratory disorder affecting about 358 million people worldwide, it poses a serious concern to analyze which factors aggravate asthmatic conditions. Various studies – observational and analytical – have suggested that air pollutants and meteorological factors can exacerbate asthma. Ambient temperature and air pollutants such as Particulate Matter ($PM_{2.5}$, PM_{10}), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Sulphur Dioxide (SO_2) have been observed to affect asthmatic symptoms among people of different age groups. This paper aims to explore the relationship between environmental factors and asthma-related hospitalization or emergency room visits. In this paper, related articles were searched on PubMed, Science Direct, and Google Scholar databases with appropriate keywords and compared. The relevance of the considered articles were evaluated based on title and abstract. The papers showed relationships between air pollutants and temperature with asthmatic exacerbations, sometimes even leading to asthma-related emergency room visits and hospitalizations. They utilize a range of analytical techniques to study the nature of the relationships between environmental factors and asthma. The selected set of papers showed a significant correlation of air pollutants and meteorological factors with asthma-related hospital visits as well as hospitalizations.

Key Words: asthma, air pollutants, meteorological factors, environmental factors

1. INTRODUCTION

Asthma is a chronic respiratory disorder that causes inflammation in the airways of the lungs. It is associated with easily triggered bronchospasms, reversible airflow limitations, and several variable and recurrent symptoms. These symptoms include wheezing, chest tightness, and cough [1]. Asthma is a rather prevalent respiratory chronic disease affecting millions of lives worldwide across a wide range of age groups in varying degrees. The frequency of the symptoms may vary from person-to-person depending on various factors that can range from pollen to air pollutants to weather conditions or even dust mites present in the immediate environment of the patient.

Air pollutant levels have been observed to demonstrate an influence on the exacerbation of asthma. The levels of Carbon Monoxide (CO), Ozone (O_3), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), and particulate matter (PM) play a significant role in triggering asthmatic symptoms and other

respiratory issues [2]. Recurrence and exacerbation of this disease among asthmatic patients often leads to emergency room visits and hospitalizations. With global warming leading to increasingly high levels of greenhouse gases such as ozone in the atmosphere, asthma patients are severely affected.

Additionally, weather conditions exhibit a substantial role in inducing or worsening of asthmatic symptoms. The influence of global warming extends to climate change which, in turn, results in a change in temperature and humidity. This change may affect asthma exacerbations [3]. Asthmatic symptoms can be triggered by weather conditions including extreme hot and cold temperatures, humidity, barometric pressure, and wind [4][5].

The studies considered are well-designed and apply appropriate analytical methods to analyze the relationship between the multiple cofounding factors and asthma exacerbations.

The need to understand the relationship between various environmental factors including air pollutants and meteorological factors arises from the importance of managing asthma. Due to the inconvenient effects of asthma on everyday life, the need to monitor and regulate the symptoms becomes a necessity. Since asthma is a prevalent disorder in most developed and developing countries, it becomes a requirement to study and analyze the effect of various factors. With no permanent cure in sight for a common chronic respiratory disorder such as this, monitoring the symptoms and its causes leads to a more responsible lifestyle aimed at preventing recurrence and exacerbation of asthma. The effects of an outdoor environment on asthma are complex and not dependent simply on the amount of exposure but associated with complex interactions with environmental factors and personal components.

2. MATERIALS AND METHODS

The evidence of the existence of relationships between environmental factors and asthma is demonstrated by several studies. Information was collected from these studies on the association of the aforementioned factors with asthma exacerbations. The studies were included in the review if they exhibited a relationship of at least one environmental factor with asthma.

A number of these studies indicate a relationship between asthma-related hospital visits and levels of air pollutants or

ambient temperature. These studies were searched on PubMed, Science Direct, and Google Scholar databases with appropriate keywords and compared. Upon searching through these databases, the titles and abstracts of the selected articles were imported into the EndNote software. To avoid redundancy, the duplicate articles were removed based on title, author, and year of publication. The relevance of the considered studies and articles were evaluated based on title and abstract.

The search keywords were “air pollution and asthma”, “meteorological factors and asthma”, “air pollutants and asthma hospital visits” and “weather and asthma hospital visits”. The studies amass a wide geographic scope from Hangzhou in China to New York in the United States.

14 studies were finally selected and these use a variety of study methodologies, analysis techniques and different factors to analyze the nature of the relationships of environmental factors with asthma. The relationships exhibited in the studies, however, vary in different geographic locations. The variation in the nature of the associations may vary due to genetic characteristics, socioeconomic status, and climate.

3. RESULTS

3.1 Air Pollutants

The first set of studies that were considered were associated with air pollution. Seven of the selected 14 studies show significant associations of asthma-related hospitalizations and emergency room visits. Air pollutants were seen to be associated with an increased risk of asthma exacerbations [5]. The selected studies for air pollutant associations were published from the year 2015 to ensure observing relatively recent analyses of the nature of their associations with asthma.

Outdoor air pollution levels demonstrate a significant link with asthma-related hospitalizations, exacerbation, decrease in lung function, and emergency room visits as evidenced by epidemiology studies [6]. Several epidemiology studies have shown that air pollution from NO₂, SO₂, ozone, and particulate matter (PM) may induce or aggravate asthma [2].

A BioSHaRE approach to associate air pollution, traffic noise, and asthma prevalence among adults speculate that long-term exposure to ambient PM₁₀ is associated with increased asthma prevalence in western European adults. It also suggests that levels of PM₁₀ and NO₂ higher by 10mgm⁻³ was associated with a greater lifetime of asthma prevalence [7]. In a time-series study based in New York City in the United States, an increase in ozone and PM_{2.5} levels were associated with a significant increase in hospital admissions among children aged 6-18 years. It analyzed the hospitalization records of New York City residents during ten years of 1999 to 2009. The study seemed to indicate an association of socioeconomic status as well as outdoor pollen with asthma exacerbation due to ozone and PM_{2.5} [8]. However, in a case study conducted in Kermanshah, Iran, the number of hospitalizations due to asthma was indicated to be

influenced by CO, ozone, NO₂ but not SO₂ or PM. Poisson regression was used to analyze the emergency room visits for asthma for associations with air pollutants and meteorological factors from September 2008 to August 2009 [9]. Compelling associations between air pollutants and asthma was also speculated in a study conducted in Seoul, South Korea. An increase in ozone was observed to be strongly associated with an increased risk of emergency department visits when 33, 751 asthma attack cases were observed during the study period of 2005-2009. An increase in the levels of NO₂ and PM₁₀ were also found to indicate a relationship with emergency department visits in a cumulative lag model [10].

Time-series and cross-over analyses were carried out in the city of Adelaide in Australia which indicated significant effects of air pollutants on asthma exacerbations for adults and children. The study further speculates that children were the more vulnerable group to the adverse effects of air pollutants. A total of 36,024 asthma admissions were considered over ten years of 2003-2013 and analyzed that the largest effects on asthma admissions related to PM_{2.5}, NO₂, PM₁₀, and pollen were found in the cool season for children (0-17 years). Ozone, however, showed the strongest association in the warm season [11]. In the city of Chongqing, China, the daily number of hospital visits due to asthma in children aged 0-18 years was collected for the year 2013. The data was analyzed by a time-stratified case-crossover design and conditional logistic regression. The study found short-term exposure to PM₁₀, PM_{2.5}, SO₂, nitrogen (N) and CO could trigger hospital visits for asthma in children. Ozone was found to have no significant effect while NO₂ seemed to play a substantial role [12]. In a recent study carried out in Jubail Industrial City in Saudi Arabia, air pollutants and meteorological factors were analyzed with asthma-related emergency department visits during the period of 2007-2011 using time-series analysis where the relative risks were measured via Poisson regression. PM₁₀, PM_{2.5}, SO₂, and NO₂ showed significant associations with an increased risk of emergency department visits. However, no significant associations were found between CO and asthma-related emergency department visits [13].

This helps corroborate an initial statement that these associations vary in different geographic locations depending on both socioeconomic status and climate. Despite evidence showing the relationship of air pollutants with damage to health, the mechanisms by which they cause exacerbations or other respiratory issues are yet to be exactly determined. However, it has been seen plausible that the histological lesions caused by pollutants in the lung parenchyma may increase the harmful effects of allergens [14].

There seems to be a consistent association of air pollutants with related emergency room visits and hospitalizations, thereby, indicating an association with exacerbations due to the increases in levels of air pollution. Table -1 shows associations of air pollutants with asthma-related hospital visits from the studies considered.

Table -1: Air Pollutants associated with Asthma-related hospitalizations and emergency department visits.
PC = Pollutants Considered, PA = Pollutants with Associations

Air Pollutants and Asthma				
First Author Name, Year	Country / Region	Age Group	PC	PA
Cai, Y., 2017	Europe	Adults	PM ₁₀ , NO ₂	PM ₁₀ , NO ₂
Goodman, J., 2017	New York, US	6-18 years	Ozone, PM _{2.5}	Ozone, PM _{2.5}
Khamutian, R., 2015	Kermanshah, Iran	General	CO, ozone, NO ₂ , SO ₂	CO, ozone, NO ₂
Noh, J., 2016	Seoul, South Korea	General	NO ₂ , ozone, PM ₁₀	NO ₂ , ozone, PM ₁₀
Chen, K., 2016	Adelaide, Australia	General (0-17 years conc.)	PM _{2.5} , NO ₂ , PM ₁₀ , ozone	PM _{2.5} , NO ₂ , PM ₁₀ , ozone
Ding, L., 2017	Chongqing, China	0-18 years	PM ₁₀ , PM _{2.5} , SO ₂ , N, CO, NO ₂ , ozone	PM ₁₀ , PM _{2.5} , SO ₂ , N, CO, NO ₂
AlBalawi, S., 2020	Jubail Industrial City, Saudi Arabia	General	PM ₁₀ , PM _{2.5} , SO ₂ , CO, NO ₂	PM ₁₀ , PM _{2.5} , SO ₂ , NO ₂

3.2 Meteorological Factors

The second set of studies that were considered were associated with meteorological factors. These factors have been observed to have a strong influence on air pollution levels or air quality. The selected studies for meteorological factors association were published from the year 2012 to ensure relatively recent observations on the nature of their associations with asthma-related hospital visits and hospitalizations.

While it has been suggested that a single meteorological factor cannot solely affect air pollution concentration, a combination of the factors—such as temperature-wind speed, temperature-pressure, humidity-wind speed—are highly correlated with the concentration of pollutants. Similar meteorological factors have different effects on the concentrations of different pollution and adjacently, different meteorological factors exhibit different effects on the concentration of the same pollutants [15].

In the city of Chuncheon in Korea, 660 emergency room visits by 583 patients due to asthma exacerbations were evaluated for the study. Daily average data was analysed in case of meteorological factors. Temperature, daily temperature range, relative humidity, wind speed, atmospheric pressure, presence of rain, solar irradiation, and presence of fog were the factors analysed for associations with asthma exacerbations and eventual emergency department visits. Among these factors, low relative humidity and high wind speed were found to be associated with an

increased risk of emergency department visits. Fog, on the other hand, was seen to be associated with a decreased risk of hospital visits [16].

A study carried out in the Southern European island country of Malta, the relationship between weather variables and hospital visits during the year 2010 was analysed for adults. Daily weather data including temperature, barometric pressure, maximum % relative humidity, mean wind speed, and precipitation were considered for the study. The hospital visits related to asthma were observed to manifest a seasonal pattern with a significantly higher number of emergency department visits in November, December, and January in contrast with a much lesser number of emergency department visits in June and July. While a positive correlation was found between precipitation and mean wind speed, and a negative correlation was found between relative humidity and barometric pressure [17].

An ecological study of time series data in the Brazilian city of Campo Grande utilized the asthma hospitalization data of children up to the age of 9 years to estimate the risk of hospitalization for asthma after exposure to ozone concentrations and climate data. It utilized a Poisson Generalized Additive Model (GAM) combined with a distributed lag non-linear model and found strong correlations of hospital admissions from January 2008 to December 2010 with precipitation, minimum temperature, and humidity, but low correlations with wind speed and ozone [18]. Another study in Shanghai, China, on asthma hospital admissions in adults utilized a similar GAM and distributed lag non-linear model combination to analyse the association between daily mean temperature and asthma hospital admissions in January 2005 and December 2012. Cold temperatures were found to be associated with higher asthma hospital admissions [19].

In Maryland, USA, a study was carried out to examine the association between extreme heat and precipitation events, and asthma hospitalization. Exposure to extreme heat and extreme precipitation events, particularly during summertime, was observed to be associated with increased risk of hospitalization for asthma in the state. The study utilized a time-stratified case-crossover design to identify that hospitalization due to asthma in extreme heat events during the summer months was more pronounced in youth and adults while those associated with extreme precipitation events were higher among <= 4-year-olds [20].

Table -2: Meteorological factors associated with Asthma-related hospitalizations and emergency department visits.

MFC = Meteorological Factors Considered, MFA = Meteorological Factors with Associations, T = Temperature, H = Humidity, AP = Atmospheric Pressure, WS = Wind Speed

Meteorological Factors and Asthma				
First Author Name, Year	Country / Region	Age Group	MFC	MFA
Kwon, J. W., 2016	Chuncheon, Korea	General	T, H, Rain, Fog, AP, WS	Fog, WS, H
Gerada, E.,	Malta,	Adults	T, AP,	T, WS,

2012	Europe		H, WS, Rain	Rain
Souza, A., 2015	Campo Grande, Brazil	0-9 years	Rain, T, H, WS	Rain, T, H
Zhang, Yue,, 2014	Shanghai, China	Adults	T	T
Soneja, S., 2016	Maryland, USA	General	T, Rain	T, Rain
Lam, H. C., 2016	Hong Kong	General	H, T	H, T
Allen, S., 2012	Brisbane, Australia	0-14 years	T	T

A time-series study was carried out in Hong Kong to examine the short-term associations of ambient temperature, other meteorological factors, and asthma hospitalizations. Poisson GAM combined with distributed lag nonlinear models and piecewise linear models were used to model associations between daily asthma hospitalizations from 2004 to 2011 and meteorological factors and air pollutants, adjusting for day of week, seasonality and trend. The study suggested that adult admissions were most sensitive to temperatures in both hot and cold seasons while admissions among children under 5 were least associated. Higher humidity and ozone levels in the hot season, and low humidity in the cold season were also associated with more asthma admissions [21]. In Brisbane, Australia, a study used an ecological design to examine the effect of extreme temperatures on emergency department admissions for children aged 0-14 years. A Poisson linear regression model combined with a distributed lag non-linear model was used to quantify the effect of temperature on asthma hospital visits during January 2003-December 2009, while controlling for air pollution, relative humidity, day of the week, season and long-term trends. Both hot and cold temperatures were associated with increases in hospital visits for childhood asthma, and their effects both appeared to be acute. Heatwaves seemed to have a slightly greater effect on asthma hospital visits while cold spells exhibit no effects [22].

The nature of the associations between meteorological factors and asthma depends on the geographical location of the area of study as well as genetic characteristics and age. Several studies and reports including the Intergovernmental Panel on Climate Change (IPCC) report speculate that extreme weather events are forecasted to increase in frequency, intensity, and duration in the near future in response to climate change [23]. While many studies indicate that weather factors are positively associated with asthma-related hospitalizations, the exact mechanisms haven't been determined by these studies.

Table -2 shows associations of meteorological factors with asthma-related hospital visits from the studies considered.

4. CONCLUSION

Air pollutants and meteorological factors have been evidenced to affect asthma-related hospital visits and admissions, and therefore, on exacerbation of asthma. While the results of these studies do not suggest the mechanism of

the effects, it shows either a positive or negative correlations between the parameters, and emergency department visits and hospitalization for asthma. Most of the studies used in this review have the limitation of assuming that the level of exposure was equal throughout the population and in different social and economic classes; and as well as the amount of time spent outdoors.

With substantial associations shown between air pollutants and asthma exacerbations, it becomes a challenge to regulate the effects of asthma in an individual without monitoring the conditions that might aggravate it. Changes in climate similarly influences the onset and recurrences of asthmatic symptoms.

From the papers selected for studying the associations of air pollutants with asthma, some studies ([8][11][12]) showed that children are highly affected by air pollutants early on in their childhood depending on the amount of exposure to the pollutants. A similar point can be substantiated for some papers ([18][20][22]) speculating on the associations between weather variables and asthma exacerbations leading to hospitalizations and emergency department visits.

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