Original Article
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Medical Journal of the Islamic Republic of Iran (MJIRI)
Iran University of Medical Sciences

The association between air pollution and weather conditions with increase in the number of admissions of asthmatic patients in emergency wards: a case study in Kermanshah

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Received: 13 January 2014 Accepted: 17 March 2015 Published: 7 July 2015

Abstract

Background: Industrialization and urbanization had a devastating impact on public health and caused an increase in health related morbidity and mortality. In fact, asthma is a chronic condition which is considered as one of the significant challenges of public health. In this study, we investigated the association of air pollution and weather conditions with excess emergency ward admissions of asthmatic patients in Kermanshah hospitals.

Methods: This was an ecological study. The total number of hospital admissions to emergency wards from all related and major hospitals of Kermanshah was collected from September 2008 through August 2009. In addition, data on air pollution as well as meteorological data were collected from the Environmental Protection Agency and Meteorological Organization of Kermanshah. To determine the association between the number of hospitalization due to asthma with those parameters, Poisson regression was used.

Results: The results of Poisson regression revealed a significant association between carbon monoxide, ozone, nitrogen dioxide and temperature with emergency room visits due to asthma in Kermanshah. No associations were found for sulfur dioxide or for particulate matter.

Conclusion: This study provides further evidence for the significant effect of monoxide carbon on asthma; and it suggests that temperature may have a role in the exacerbation of asthma. However, due to the multi-factorial nature of asthma, other factors also play a major role in the development and exacerbation of this illness.

Keywords: Air Pollution, Asthma, Weather, Iran.

Cite this article as: Khamutian R, Najafi F, Soltanian M, Shokoohizadeh MJ, Poorhaghighat S, Dargahi A, Sharafi K, Afshari A. The association between air pollution and weather conditions with increase in the number of admissions of asthmatic patients in emergency wards: a case study in Kermanshah. *Med J Islam Repub Iran* 2015 (7 July). Vol. 29:229.

Introduction

Asthma is a common respiratory disease whose prevalence has been increasing throughout the world in the recent years (1,2). Factors associated with the incidence and exacerbation of asthma include genetic

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factors, respiratory tract infection, stress, poor nutrition, exposure to allergens such as pollen and mold spores, tobacco smoke, adverse weather conditions, air pollution and certain social factors (3-9). Among all factors, air pollution and adverse weather conditions play an important role in the development and exacerbation of asthma (10). Air pollutants contributing to asthma exacerbations include sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, smog and particulate (usually particles between 2.5 and 10 microns) (11).

In many epidemiological studies, the association between the number of hospital admissions of asthmatic patients with air pollution and climatic factors has been investigated. While the results of most of such studies indicated that air pollutants and air quality have a major role in exacerbation of asthma (12-15, 16-18), other studies reported no significant association ,(19-21) or even a negative association (22).

Studies have shown that in the developed countries of Europe and North America, due to the strict environmental regulations, air pollution as one of the important risk factors for asthma exacerbations, has been controlled in the recent years (23). However, due to the multi-factorial nature of asthma, it is still a major challenge in these countries (24, 25).

In contrast, in developing countries, with rapid urbanization and lack of proper implementation of environmental legislation, air pollution is increasing rapidly (26-28). Iran, as a developing country, has been faced with air pollution in many of its large and industrial cities in the recent years. Studies also indicated that the prevalence of asthma in many cities of Iran is more than the world average and the trend in the prevalence of asthma is growing (29, 30). Kermanshah, a city located in the west of Iran, is considered as one of the industrial cities of this country. According to WHO, Kermanshah has been considered as one of the ten most polluted cities in the world in 2011(31). Since no studies have been done on the effect of air pollution on hospitalization of asthmatic patients in Kermanshah, the current study aimed to determine the association between air pollution levels and weather with excess emergency ward admissions of asthmatic patients in Kermanshah hospitals.

Methods

Study Area

Kermanshah is located in the West of Iran at 34° 18’ latitude North and 47° 4’ longitude East. It is located 1420 meters above the sea level; and its average, maximum and minimum annual temperature are 14.2, 38 and 3.2 ºC, respectively. The area of this city is 8547 square kilometers and its population, according to Census 2010, is already more than 980,786.

Data

This was an ecological study. Overall, there are 10 public and private hospitals in the urban area of Kermanshah. Of them, seven were included in the study, and the others (the Obstetrics and Gynecology and Psychiatric Hospitals) that were not related to the aim of this study were excluded. The total number of hospital admissions to emergency wards with the diagnosis of asthma from seven major hospitals (Imam Reza, Imam Hussain, Imam Khomeini, Bisotoun, Shohada, Artesh and Hazrat Masomeh) was collected from September 2008 through August 2009.

The daily number of asthmatic patients was gathered from all included hospitals (emergency wards), retrospectively. The patients diagnosed as suffering from "asthma" had been extracted by a trained healthcare provider. The diagnosis made by the attending physician was classified according to the International Classification of Diseases, and code J_{44}-$_{46}$ (asthma, acute severe asthma and chronic obstructive asthma). From all admissions, only those who were residents of Kermanshah district were included.

For the study period, data on concentration levels of air pollutants was collected from the Environmental Protection Agency

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of Kermanshah. The daily concentrations of each pollutant were averaged from the available monitoring results of three fixed stations located in the urban district of Kermanshah. Pollutants measured by these stations were sulfur dioxide (SO_2), nitrogen oxides, carbon monoxide (CO), particulate matter with less than 10 µm of aerodynamic diameter (PM_{10}), and ozone (O_3). For the purpose of this study, the mean hourly values of the above mentioned pollutants from 1:00 am to 12:00 pm were considered.

Based on the previous reports (19-21), major meteorological data (temperature, air pressure, relative humidity and rainfall) were obtained from Kermanshah Meteorological Organization. These data were all of the climatic factors measured by this Organization.

Statistical Analysis

Data processing and analysis were performed with SPSS 21 software. In order to measure the association between the daily number of emergency ward admissions with diagnosis of asthma with different air pollutants and climate parameters, we first investigated the possible collinearity between climate parameters and air pollutants by looking at the correlation between such factors using Pearson's bivariate correlation. Then, among the factors that had a high correlation with each other (correlation coefficient > 0.7), only one of them were included in the final model. According to Pearson's bivariate correlation NO and NO_X had high collinearity with NO_2 and CO, so they were removed in the multivariate model. Among NO_X, NO and NO_2, just NO_2 was used in the multivariate Poisson regression because of its higher importance in human health.

To determine the association between the number of hospital admissions with the diagnosis of asthma with air pollution and climate parameters, Poisson regression was used. In order to check the independent effect of each factor on the number of hospital admissions with the diagnosis of asthma, we used multivariable models.

Table 1. Number of Patients Admitted to Hospitals in Different Age Groups during 2008-2009

Age	Frequency	Percent
0-13 (Children)	58	13.15
15-30 (Adolescents)	87	19.7
30-65(Adults)	206	46.7
65 < (Elderly)	90	20.4
Sex		
Male	193	43.8
Female	248	56.15

Results

For the period of the study, 441 patients with the mean±SD age of 44.02±19.1 years who were diagnosed with asthma referred to Kermanshah hospitals. Among the total patients, women (56.1%; N = 248) and those who were in the adult age group (46.7%; N = 206) constituted the largest groups (Table 1). According to Fig. 1, the highest number of admissions of the asthmatic patients was in the winter and the month of December, and the lowest was in

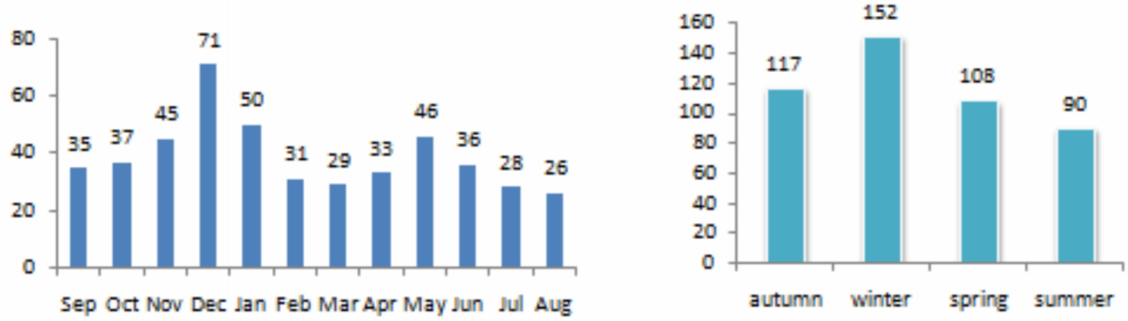

Fig. 1. Number of Asthmatic Patients Attending to Hospitals in Different Months during 2008-2009

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Table 2. Descriptive Statistics of Air Pollutants in Different Months during 2008-2009

Month	O_3(ppb)	NO (ppb)	NO_2(ppb)	NO_x(ppb)	PM_{10}(ug/m3)	SO_2 (ppb)	CO (ppm)
Sep	17.3±5.38*	19.5±12.03	8.7±3.15	28.2±14.93	142.5±64.53	27.5±5.29	1.6±0.78
Oct	3.9±3.80	29.2±10.99	10.6±2.31	39.7±12.90	87.6±33.70	25.2±3.63	2.6±0.68
Nov	2.6±0.17	43.9±23.93	13.8±3.28	57.7±26.45	67.6±15.49	24.5±1.62	2.5±0.86
Dec	3.5±1.66	34.2±19.40	16.0±3.71	50.2±21.29	77.2±29.68	22.0±2.31	2.1±0.76
Jan	5.0±1.37	20.0±11.51	12.9±2.71	32.9±13.66	106.7±95.47	26.0±3.02	1.7±0.74
Feb	6.3±2.06	19.0±12.18	12.4±2.11	31.3±13.79	149.74±128.9	19.7±5.2	1.6±0.75
Mar	8.2±2.38	14.0±7.11	10.7±2.74	24.4±9.04	138.8±80.90	18.0±4.75	1.4±0.56
Apr	6.9±1.81	15.9±6.65	9.3±1.63	25.2±7.8	164.3±78.4	24.7±5.95	1.6±0.54
May	33.0±12.4	12.8±6.5	7.7±2.3	20.5±8.6	193.1±120.2	43.2±15.6	1.2±0.52
Jun	40.2±4.99	11.6±4.86	7.4±1.99	19.1±6.57	457.7±345.4	51.4±16.21	1.0±0.32
Jul	40.7±6.92	12.3±5.28	7.6±2.33	20.0±7.47	205.4±76.08	61.1±21.46	1.1±0.43
Aug	34.7±9.07	11.57±5.57	6.7±1.97	18.2±7.35	137.6±47.7	60.2±23.21	1.1±0.39

Mean±SD

Table 3. Descriptive Statistics of Climatic Factors in Different Months during 2008-2009

Month	Temperature	Rainfall	Pressure	Ave. Hum.
Sep	19.8±2.09*	0.0±0.00	870.9±2.53	28.5±8.07
Oct	10.8±3.4	3.3±7.4	872.5±1.88	64.8±15.11
Nov	5.0±3.6	1.89±6.76	872.3±2.30	61.2±13.27
Dec	2.0±4.5	1.0±3.95	872.1±3.29	62.9±16.5
Jan	5.4±3.09	2.2±5.96	869.9±2.63	68.0±10.87
Feb	7.9±3.51	0.5±1.08	868.6±3.17	58.0±11.2
Mar	10.09±1.79	1.9±3.6	866.5±2.9	60.4±11.24
Apr	16.9±2.67	0.2±0.89	869.1±1.56	53.3±11.8
May	23.9±2.1	0.1±0.03	867.2±1.6	27.9±6.1
Jun	28.19±1.14	0.0±0.02	862.9±2.26	20.6±4.8
Jul	28.1±2.7	0.0±0.05	863.5±3.3	19.1±5.1
Aug	24.1±2.5	0.4±2.08	866.8±2.15	27.1±13.5

Mean±SD

the summer and the month of August ($p<0.05$).

In December, the mean±SD values of climatic parameters, including ambient temperature, precipitation, humidity and pressure were obtained to be 2.0±4.5C^0, 1.0±3.95mm, 872.1±3.29 and 62.9±16.5, respectively; and the values of air pollutants such as ozone, nitrogen monoxide, nitrogen dioxide, NO_X, particulates, sulfur dioxide and carbon monoxide were calculated to be 3.48 ppb, 34.23 ppb, 15.97 ppb, 50.18 ppb, 77.21 ppb, 22.04 ppb, 2.09 ppm, respectively (Tables 2 and 3).

As mentioned above, the lowest rate of admission of asthmatic patients was in August; and in this month, the mean values of climate variables, ambient temperature, precipitation, barometric pressure and humidity were obtained to be 24.1±2.5 Cº, 0.4±2.08 mm, 866.8±2.15, 27.1±13.5, respectively. Also, the amount of air pollutants such as ozone, nitrogen monoxide, nitrogen dioxide, NO_X, particulates, sulfur dioxide and carbon monoxide was 34.67ppb, 11.47ppb, 6.67ppb, 18.2ppb, 137.62g/m^3µ, 60.17ppb, 1.14ppm, respectively (Table 2, 3).

Table 4 demonstrates the minimum, maximum, mean, standard deviation, and also the most critical days of pollutants and climatic factors that have been presented in 2008–2009. Accordingly, the maximum values of pollutants including NO_X, NO, NO_2 and CO occurred during the winter, and the highest levels of SO_2 and PM_{10} and O_3 concentration occurred in the summer.

The results of univariate Poisson regression showed that carbon monoxide, nitrogen oxides (NO, NO_2, NO_X), humidity and temperature were significantly associated with the number of hospital admissions of asthmatic patients ($p<0.05$).

According to the multiple regression analysis, among the air pollutants and climatic parameters, temperature, ozone and carbon monoxide were significantly associated with the admission of asthmatic pa-

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Table 4. Descriptive Statistics of Daily Values of Air Pollutants and Climatic Factor

Measured Daily Variable	Minimum	Maximum	Mean	Std. Deviation	The Day with Extreme Value
O_3, ppb	.00	52.38	17.2	16.0	2009/August/12
NO, ppb	1.13	92.67	19.9	14.96	2009/January/4
NO_2, ppb	2.00	23.54	10.2	3.7	2009/January/17
NO_X, ppb	4.29	111.88	30.2	17.85	2009/January/4
PM_{10}, ug/m^3	.00	2758.60	162.6	223.14	2009/July/5
SO_2, ppb	7.42	101.63	33.9	19.26	2009/July/23
CO, ppm	0.31	4.24	1.6	0.798	2008/December/6
Tem,°C	-5.20	30.50	15.3	9.54	2009/August/17
Rain, mm	.00	26.90	0.9	3.56	2008/October/26
Pressure	858.70	881.70	868.5	3.91	2009/January/14
MinHum, %	3.00	93.00	23.9	17.70	2009/January/21
MaxHum, %	21.00	100.00	67.1	27.57	2008/November/1
AveHum, %	12.50	97.00	45.6	21.52	2009/January/21

Table 5. Univariate and Multiple Poisson Regression Models to Determine the Association between Air Pollutants and Weather Conditions, with the Number of Asthmatic Patients Admitted to Hospitals in Kermanshah

Parameter		Univariate Model β* (0.95 CI)	Multiple Model B*(0.95 CI)
Air Pollutants	CO	0.220 (0.122 – 0.325)	0.165(0.009 – 0.322)
	O_3	-0.001 (-0.01 – 0.0009)	0.016(0.003 – 0.0276)
	NO**	0.0119 (0.007- 0.017)	-
	NO_2	0.054 (0.03 – 0.079)	0.014(-0.024 – 0..054)
	NO_X**	0.011 (0.006 – 0.015)	-
	PM_{10}	0.001 (-0.001 – 0.0003)	0.0004 (-0.001 - 0.001)
	SO_2	-0.004 (-.009 - 0.001)	0.0046 (-0.007 – 0.016)
Weather Conditions	Temperature	-0.021 (-0.031- -0.012)	-0.027(-.048 - -0.006)
	Rain	0.005 (-0.02 - 0.03)	0.007(-0.02 - 0.032)
	Pressure	0.049 (-0.024 - 0.073)	0.023 (-0.01 - 0.055)
	Humidity	0.006 (0.002 - 0.011)	0.008 (-0.003 – 0.02)
Season	Spring	-	-
	Summer	--0.191 (-0.544-0.148)	-0.35(-0.880-0.169)
	Autumn	0.104(-0.23-0.469)	Omitted by software
	Winter	0.518(0.169-0.879)	0.549(0.086-0.90)

tients in Kermanshah hospitals (Table 5).

In both univariate and multiple Poisson regression, no significant associations were found for sulfur dioxide or PM_{10} ($p<0.05$). The results of Poisson regression models showed the highest significant association between carbon monoxide and emergency room visits due to asthma with coefficient regression of 0.220 (0.122 – 0.325) and 0.165(0.009 – 0.322).

In addition, using the multivariate model, we found a positive association between the number of emergency ward admissions for asthmatic symptoms and cold season (winter).

Discussion

Based on the results of multivariate Poisson regression, among air pollutants, CO and O_3 were significantly associated with the number of hospitalization of asthmatic patients in Kermanshah. In the studies performed in Washington, Taiwan, Korea and Australia both CO and O_3 were associated with the increase in the number of patients with diagnosis of asthma (32-35).

However, such findings are not consistent with other reports (36-38).

According to the univariate model, carbon monoxide and nitrogen oxides, which include all of NO, NO_2 and NO_X, were associated with hospital admissions with diagnosis of asthma; and among these variables, the greatest influence was related to NO_2. In fact, the toxic effect of NO_2 on human health is about 4 times greater than NO (39). Our finding is in line with that of other similar reports (14, 15, 40-42).

In this study, in both single and multivariable models, no significant association was

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obtained between PM_{10} and the number of asthmatic patients admitted to hospitals in Kermanshah. In a study conducted by Lavin et al. in Canada, no significant association was found between the particles and the number of asthmatic patients admitted to hospital in all age groups, while carbon monoxide, NO_2 and SO_2 had the greatest impact on the rate of asthmatic patients' admission to emergency departments (40).

Moreover, in other studies, there were no significant associations between particles and the rate of hospitalization of asthmatic and respiratory patients, but gaseous pollutants played an important role in the exacerbation of asthma (43-46).

However, in many studies, in addition to the gaseous pollutants, particulate matters were associated with a number of asthma admissions to the hospitals. For example, in 2011 a study was conducted in Italy showing that CO, SO_2, NO_2 and PM_{10}, were associated with asthma hospitalization (14). Such findings were repeated in other studies showing an association between CO, NO_2 and PM_{10} with the number of hospitalization of patients with asthma and respiratory diseases (15, 41). In a study conducted in Barcelona, PM_{10} and NO_2 were significantly associated with the number of asthma patients visiting EDs, while SO_2 and O_3 showed no significant association (42). In 2006, in Taiwan a significant positive association was found between NO_2, CO and PM_{10} with the number of hospital admission of asthmatic children (12). In another study conducted in Athens in 2011, PM_{10}, SO_2 and ozone had a significant positive association with the number of emergency admissions of asthmatic patients (47).

In fact, in the recent years, just like other cities in western Iran, Kermanshah has been faced with a hazy weather resulting from successive droughts in the neighboring countries; and therefore, people are more aware of the effect of the particulate matter (PM_{10}) on their health. For that reason, on such days, people go out less than other days; and this may contribute to the lack of effect of the particulate matter on the number of hospital admissions due to asthma in this study.

In this study, no significant positive association was found between SO_2 levels and hospitalization of asthmatic patients. Other reports revealed different results; while some of such reports showed no association (12, 42, 45), others found a positive association (14, 40, 43, 47).

Using univariate Poisson regression model, among climatic factors, temperature and humidity and winter were significantly associated with the number of hospital admissions of asthmatic patients in Kermanshah ($p<0.05$); and the most hospital admissions were in the winter with maximum humidity and minimum temperature. In a study conducted in China in 2006, the highest number of hospital admissions due to asthma was in the winter and the lowest was in the summer and early autumn (12).

In a study by T.Abe in 2008 (11) and Samoli, in 2011(47), low temperature and cold weather were significantly associated with asthma exacerbations. In contrast, a study was conducted in 2011 by Tramuto et al. in which the severity of asthma in the summer was significantly more than the other seasons (14). In another study conducted in Australia by Jalaludin, it was found that the impact of air pollutants on asthma exacerbations was more in the warmer months than in the other months (35). In the present study, a significant association was found between the rate of hospital admission of asthmatic patients and levels of pollutants such as NO_2, CO and O_3. It should be noted that asthma is only one of the adverse effects of air pollution on public health.

Conclusion

This was an ecological study and did not take into consideration the behavioral characteristics of individuals, such as nutrition, physical activity, smoking and socioeconomic status which have significantly contributed to occurrence and exacerbation of asthma.

In fact, the government should reduce air

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pollution in the city of Kermanshah by taking more precise and serious actions in the form of short-term and long-term plans. Also, more serious environmental regulations should be implemented. As a short-term plan, it is recommended that urban air quality be monitored, and in the days that air pollution is higher than the permissible values, weather condition should be announced to all people specifically those with higher risk for respiratory diseases.

Acknowledgments

The present study was adopted from the final report of a research project approved by the Department of Research and Technology of Kermanshah University of Medical Sciences. The authors would like to thank Kermanshah Meteorological Organization, Kermanshah Department of Environment and hospital officials of Kermanshah for the material support.

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