EJMI

DOI: 10.14744/ejmi.2019.56609
EJMI

Research Article

The Effect of Air Pollution on Respiratory System Disease Admissions and Health Expenditures

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Abstract

Objectives: Air pollution increases hospital admissions due to respiratory system diseases. This study aims to investigate health expenditures due to hospital admissions in Erzincan, Turkey.

Methods: We acquired data on daily admissions of patients with respiratory system diseases from 2015 to 2016 in Erzincan from Mengücek Gazi Education and Research Hospital (MGERH). Concurrent air quality monitoring data were obtained from the Ministry of Environment and Urbanization, and meteorological data from General Directorate of Meteorology. Risk analyses were performed via the STATA® program, followed analyses of health expenditures based on patient treatment costs obtained from the Social Security Institution.

Results: In Erzincan, a total of 78.793 patients (56.5% female, 43.5% male) presented to the emergency service and clinical departments of MGERH with respiratory complaints. The highest frequency diagnosis was upper respiratory system infections and most patients fell into the age groups of 15-34 and 45-64. A correlation was obtained between the amount of particulate matter 10 µm and smaller, one of the air quality parameters monitored in Erzincan.

Conclusion: Increases in air pollution levels similarly increase the number of hospital admissions secondary to respiratory system diseases by 0.72%. According to Social Security Institution data, average per capita health expenditures related to these admissions were 44.338.98 USD.

Keywords: Air pollution, Erzincan, respiratory system

Cite This Article: *Ünver E, Bolat E, Altın S, Çoban A, Aktaş M, Fıçıcı M, et al. The Effect of Air Pollution on Respiratory System Disease Admissions and Health Expenditures. EJMI.*

Air pollution is a significant health risk factor in Europe, and all over the world. A global study of diseases showed that air pollution is one of the top ten global health risk factors. Approximately 7 million people in the world and 400.000 people in the European Union (EU) experience early death due to air pollution.[1]

The effects of air pollutants on health can be acute or chronic. Acute effects increase hospital admissions and hospital treatments within hours or days following exposure, whereas chronic effects take the form of chronic diseases onset, exacerbation, and early death. Exposure to outdoor air pollution is associated with acute and chronic health problems that range from minor irritation to death.[2]

In this study, we estimated the relative increase in the frequency of hospital admissions coinciding with increases in air pollution levels. We also sought to predict the fiscal im-

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Submitted Date: February 16, 2019 **Accepted Date:** February 18, 2019 **Available Online Date:** February 28, 2019

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plications of these increases by evaluating the correlation between increases in hospital admissions and air pollution levels in the Erzincan province of Turkey where levels of air pollution have been gradually increasing.

Methods

Air Pollution and Health Data

We obtained the number of patients with daily respiratory system disease codes in 2015–2016 from the Erzincan University Mengücek Gazi Education and Research Hospital records.

Air pollution monitoring station data were obtained from Turkey's Ministry of Environment and Urbanization Clean Air Directorate website, and meteorological data were taken from the General Directorate of Meteorology.

Statistical Analysis

Numerous study designs have been used to evaluate correlations between daily air pollutant concentrations and acute changes in mortality and morbidity. Well-known air pollution time series analyses, such as the Air Pollution and Health: a European Approach (APHEA) in Europe or the National Morbidity, Mortality, and Air Pollution Study (NMMAPS) in the U.S. are examples of such investigations.[3, 4] However, the case-crossover design, initially defined in 1991,[5] provides an alternative estimation approach for evaluating acute symptoms.[6] The case-crossover design compares the ambient concentrations of air pollutants at an event with concentrations on a control day. This design also permits the consideration of individual characteristics such as gender, age, and lifestyle or health status factors to evaluate the effects of increases in air pollution among susceptible subgroups, or to explore the effects of changes in air pollutant concentrations by individual characteristics.[7, 8] The study population consists of subjects or cases that were affected by respiratory symptoms in a case crossover design. The design focuses on the point in time when the event occurred.[7] A symmetric bidirectional case-crossover design was used in this study. For each case, we compared the concentration PM 10 at the time of admission (the case period) with a level obtained in a specified time period before and after the hospital admission event (the control period). Control days were the same days of the week as the case days. Cases in this analysis include adults and children in the study area who presented with respiratory symptoms during the two-year study period. Additional controls included: seasons (summer, autumn, winter and spring) and meteorological parameters (temperature, cloudiness, pressure, average wind speed and maximum wind speed). The acute respiratory effects of exposure to increased air pollution levels may be immediate, or may occur several days after exposure. Increased admissions exhibit strong correlations with air pollution levels on the day of admission, and up to four days afterward.[9, 10] In this study, a lag of the four days preceding admission was used to examine the effect of PM lag days, ending on the day of admission. Control periods of two weeks before and after the day of admission were used in this analysis. By selecting two weeks before and two weeks after the admission date as the control, we avoid possible confounding of results resulting from the effects of day of the week, seasonality or chronic trends. Conditional logistic regression models were applied in this study for the case-crossover design using the Stata statistical package's clogit procedure.[11] Conditional logistic regression analysis was used to estimate adjusted odds ratios (ORs). We calculated ORs for PM 10 with respect to respiratory-related admissions, after adjusting for weather conditions including daily temperature, average relative humidity, pressure, cloudiness, and average and maximum wind speeds. The results of previous studies indicated that increased mortality or hospital admissions were associated with high air pollution levels on the day of, or the days preceding, admission.[9, 10] Thus, we used a cumulative lag of up to four preceding days. The associations between hospital admissions and levels of air pollutants were estimated using ORs and 95% confidence intervals (CIs). These were produced through conditional logistic regression with weights equal to the number of admissions one particular day. The ORs were calculated on the basis of incremental exposure, corresponding to a 10-mg/m^3 increase in pollutant concentrations.

We performed risk analyses using the case-crossover method and conditional logistic regression with the epidemiological data, air pollutant (PM 10) data, meteorological conditions, age, gender, and location, all of which were independent variables. Risk periods were determined by examining the temporal changes in disease prevalence.

For each case, we compared the level of PM 10 on the day of hospital admission to the level of PM 10 during a specified time period prior to, and after, admission. The cases were days within the study period where the patient underwent treatment for respiratory disease, and the control days were defined as the two weeks before and two weeks admission. All meteorological variables were kept constant in each analysis. The acute effects of air pollution can occur immediately, and can also be seen a few days after the onset of increased pollution levels. In this study, we included the PM 10 concentrations over the preceding four days in the analysis to determine the effect of PM 10 (lag1, lag2, lag3, lag4) levels on hospital admissions four days prior to the previous day. We calculated the OR values of the re-

spiratory system diseases and PM 10 which give the risk level probabilities, using Stata 14.0 software. The level of relationship between air pollution levels and hospital admissions were calculated using OR at a 95% confidence interval.

OR was calculated on the basis of estimating increases in hospital admissions, versus increases of 10 μg/m^3 in air pollutant (PM 10) concentrations. The risk ratios obtained were multiplied by the daily costs of diseases taken from the Social Security Institution and the resultant health-related expenditures were calculated.

Results

A total of 78.387 patients (56.7% female, 43.3% male) were admitted to the Erzincan University Mengücek Gazi Training and Research Hospital emergency department, or outpatient clinics, between 2015–2016 due to respiratory symptoms. Upper respiratory tract infections were diagnosed at a frequency of 29.3%, and the patients diagnosed with this disease were predominately ages15–34 or 45–64 (Table 1).

In the two-year period, 33.929 male patients, ages 15–34 years, presented with frequent cough, dyspnea, and acute bronchitis (Table 2). In contrast, 44.458 female patients, aged 45–64 years, were diagnosed with asthma during the same period (Table 3).

For 2015–2016, we determined the relationship between PM 10 levels and patient admissions in Erzincan in 2015–2016. The average concentration of PM 10 over the study period was 67.46±31.38 μg/m^3. For 122 days PM 10 was greater than 100 μg/m^3 and for 52 days PM 10 was greater than 150 μg/m^3. The correlation coefficient (r) between the number of daily respiratory disease examinations and PM 10 levels was moderately strong and positive at 0.36, $p<0.05$ (Fig. 1).

Table 1. Two-year total hospital admissions, according to diagnosis and age group

Age Group	Diagnosis						
	URTE	Acute Bronchitis	Sinusitis	COPD	Asthma	Cough & Dyspnea	Total
0–14	6471	2087	25	349	874	2040	11846
15–34	9797	3346	390	39	3848	3074	20494 (26.1%)
35–44	2838	2238	171	79	2908	1549	9783
45–64	2937	5117	238	1502	7659	3274	20727 (26.4%)
>64	942	3189	64	3313	5348	2681	15537
Total	22985 (29.3%)	15977	888	5282	20637	12618	78387

Table 2. Two-year hospital admissions formales, according to diagnosis and age group

Age Group	Diagnosis						
	URTE	Acute Bronchitis	Sinusitis	COPD	Asthma	Cough & Dyspnea	Total
0–14	3586	1045	13	186	525	1194	6549
15–34	5117	1530	130	23	1317	1690	9807
35–44	1490	763	58	57	792	639	3799
45–64	1360	1538	56	1237	1748	1345	7284
>64	421	1069	25	2540	1325	1110	6490
Total	11974	5945	282	4043	5707	5978	33929

Table 3. Two-year hospital admissions for females, according to diagnosis and age group

Age Group	Diagnosis						
	URTE	Acute Bronchitis	Sinusitis	COPD	Asthma	Cough & Dyspnea	Total
0–14	2885	1042	12	163	349	846	5297
15–34	4680	1816	260	16	2531	1384	10687
35–44	1348	1475	113	22	2116	910	5984
45–64	1577	3579	182	265	5911	1929	13443
> 64	521	2120	39	773	4023	1571	9047
Total	11011	10032	606	1239	14930	6640	44458

The results obtained using the case-crossover design with different lag times were subjected to logistic regression analysis with adjustment for meteorological variables. Table 5 provides separate adjusted ORs and their 95% CIs for exposures to PM 10 pollutants in relation to respiratory-related hospital admissions. We averaged the pollution level of the day or admission with the four days preceding admission in order to determine the estimated pollutant exposure level. Estimates of percent increase in morbidity are shown for each 10 μg/m^3 rise. Table 6 shows an association between an elevation in short-term air pollution levels and respiratory hospital admissions for PM 10. For PM 10, there were consistent and significant positive associations with respiratory-related hospital admissions for both males and females (Table 4).

The number of respiratory-related hospital admissions increased by 2012 people as a result of air pollution (977 men, 1035 women) over the two-year study period.

The highest numbers of hospital admissions were due to cute bronchitis in males in 2015 and asthma in females in 2016.Associated symptoms included upper respiratory infection (URI) in males, coughing in females, and dyspnea due to air pollution. From the perspective of age groups, it was seen that the highest increase in the number of admissions was among males aged 35–44 and females aged 15–34.

When we pooled the genders, the 15–34 age group was found to have the highest risk of respiratory-related hospital admission. The second highest-risk group were those patients >65 years-old.

Acute bronchitis was the diagnosis most frequently associated with respiratory-related hospital admissions due to increased air pollution, followed by URTE, asthma, cough, and dyspnea, respectively.

When the number of patients in the risk group was calculated as a percentage of the number of patients of the same age and sex in the relevant disease group when the PM 10 level increased by 10 μg/m^3, a group with 2.57% increased risk was detected. The risk ratios according to disease groups and age groups are summarized in Table 7.

Male and female risk group rates were 2.88% and 2.33%, respectively. The risk ratios according to age groups in males and females are given in Table 8.

Within the scope of this study, we calculated health-related expenditures totaling 1.790.906.71 USD (5.384.720.14 ₺)related to the treatment of 78.387 patients at Erzincan Mengücek Gazi Training and Research Hospital from 2015–2016. This calculation was based on Social Insurance Institution's daily cost of diseases database.

We multiplied the number of high risk group patients for each diagnostic category, multiplied by the estimated

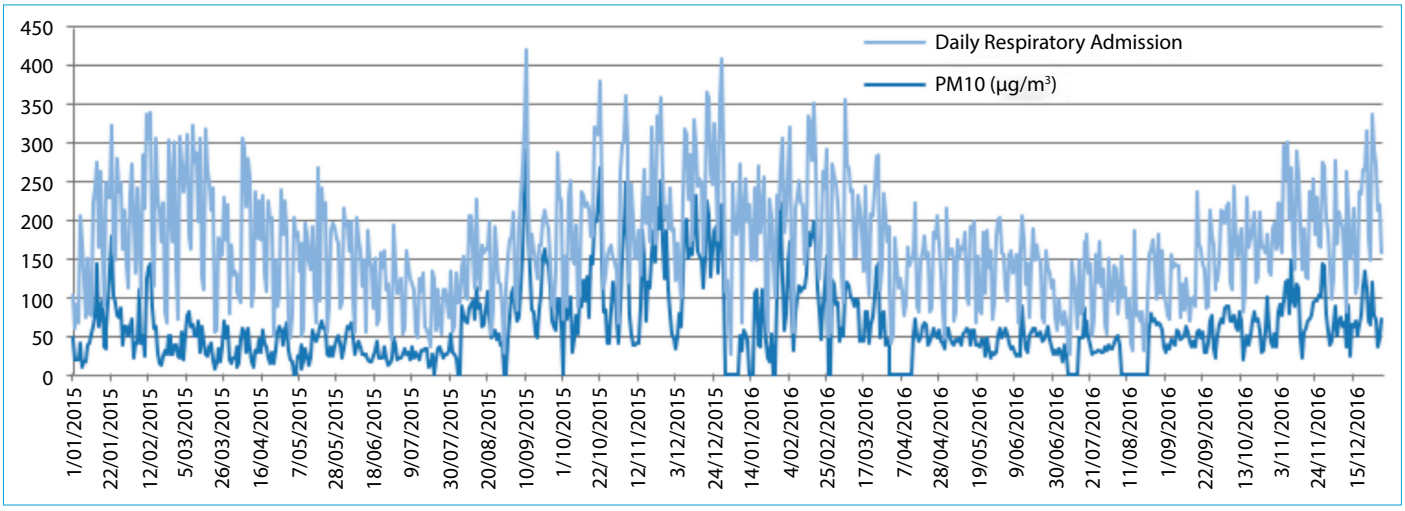

Figure 1. Number of respiratory-related admissions and daily PM10 levels in Erzincan.

Table 4. Number of admissions and air pollution averages over weekdays and weekends

Averaging Period	N (days)	PM10 (μg/m^3)	SD of PM10, (μg/m^3)	p	Daily Respiration Examination	SD (Daily Respiration Examination)	p
Weekdays	500	70.36	±49.3	<0.05	134.2	±54.4	<0.05
Weekends	231	61.28	±41.2		50.6	±23.1	
Total average	731	67.46	±47		107.8	±21.9	

Table 5. Adjusted odds ratios (OR) for respiratory-related hospital admissions (with 95% confidence intervals)

Age group/diagnosis		OR (10 µg/m³ increase)	P>z	95% CI	
Male					
0–14/case_URTE	PM10_lag4	1.024	0.008	1.006	1.042
15–34/case_acutebronch	PM10	1.028	0.044	1.001	1.057
35–44/case_asthma	PM10	1.056	0.014	1.011	1.101
35–44/case_coughDyspnea	PM10_lag2	1.064	0.048	1.000	1.130
45–64/case_coughDyspnea	PM10_lag2	1.051	0.016	1.009	1.095
64+/case_ acutebronch	PM10_lag4	1.045	0.005	1.014	1.077
64+/case_KOAH	PM10	1.024	0.033	1.002	1.046
	PM10_lag3	1.031	0.021	1.005	1.057
Female					
0–14 /case_coughDyspnea	PM10_lag1	1.081	0.002	1.030	1.134
35–44/case_coughDyspnea	PM10	1.044	0.040	1.002	1.088
45–64/case_acutebronch	PM10_lag2	1.031	0.010	1.008	1.054
45–64/case_asthma	PM10_lag4	1.020	0.000	1.006	1.033
65+/case_acutebronch	PM10_lag3	1.026	0.070	0.998	1.056

Table 6. Increases in the number of patients referred for PM10 exposure (OR 10 µg/m³ PM10 increase) for the two-years study period

Age group	URTE	Acute Bronchitis	COPD	Asthma	Cough & Dyspnea	Total
0–14	336	45			47	428
15–34	124	221		48	78	471
35–44	71	118		61	107	357
45–64		95	42	151	24	313
> 64	24	110	129	114	66	443
Total	555	589 (29.3%)	171	374	322	2012

Table 7. The percentage of increases in PM10 exposure (OR 10 µg/m³ increase) over the two-years study period

Age group	URTE	Acute Bronchitis	COPD	Asthma	Cough & Dyspnea	Total
0–14	5.19	2.16			2.30	3.61
15–34	1.27	6.60		1.25	2.54	2.30
35–44	2.51	5.27		2.10	6.91	3.65
45–64		1.86	2.79	1.98	0.74	1.51
>64	2.50	3.45	3.90	2.13	2.46	2.85
Total	2.41	3.69	3.24	1.81	2.55	2.57

health-related expenditures as per the Social Security Institution and added the total [$44.338.98 (133.016.91₺)] as an additional expense. This amount was 2.47% of the total expenditure. Acute bronchoconstriction was 3.69% and COPD was 3.47%.

Table 8. The percentage increase in risk associated with PM10 exposure (OR total of two years for an increase of 10 µg/m³)

Age Groups	Risk Rates	%
	Male	Female
0–14	0.68*	0.37
15–34	0.55	0.64*
35–44	0.67*	0.33
45–64	0.31	0.40
> 64	0.68*	0.59
Total	2.88*	2.33

*p<0.05.

Discussion

Air pollutants (PM 10, PM2.5, SO_2, nitrous oxide, ozone) exert adverse health effects, even at low levels. PMs have variable effects according to their sizes. In addition, PMs exhibit serious health effects as a result of the many different

organic and inorganic pollutants that can be found with the particulate matter composition.[12]

According to the European Environmental Agency (EEA), 97.2% of the urban population in Turkey was exposed to unhealthy levels of PM 10.[13] We did not examine PM2.5 since only PM 10 was monitored over the study period of 2015–2016. An increase of 10 μg/m^3 in PM 10 level caused an increase in the number of respiratory-related hospital admissions by 2.57%. People with cardiac or pulmonary diseases, such as asthma, COPD, and heart disease are at increased risk of morbidity and mortality when exposed to PM 10.

Elderly individuals are more susceptible to PM 10 exposure. This group is more vulnerable to risks related to admission to hospitals or emergency departments, and early death from heart or lung disease.[14] In this study, the age groups with the highest riskwere15–34 years old and >65 years old (Table 5).

In a study conducted in Düzce in 2009 determined that a PM 10 concentration of more than 100 μg/m^3 was not associated with observed rates of COPD, asthma or the rate of admission to emergency services.[15] In the same study, it was found that the number of urgent admissions for COPD among elderly males (>65 years old) increased in winter, while the number of urgent admissions for asthmain elderly females increased in autumn. In this study, the highest risk group, in both genders, was patients with acute bronchitis.

Air pollution is an important environmental problem in Turkey and should not be overlooked. Unfortunately, according to the World Health Organization (WHO) air quality standards, the monitoring data continues to detect high levels of pollutants. A research project involving 25 European cities showed that adapting to the WHO's 10 μg/m3 standard for annual average PM 2.5 concentrations increases the average life span of people aged 30 years and older by 22 months.[16] Erzincan is a community where the incidence of death among those aged 35 years and older is 30% more than the nationwide average (as high as 13.3%) These findings highlight the effects of pollution on survival.[17] Coal fumes contribute to air pollution with NOx, SO_2, PM and tropospheric ozone. Exposure to fine particulates (PM 2.5) at certain levels over a long period of time can lead to COPD. According to a recent systematic screening and meta-analysis, exposure to a concentration of total suspended solids (TSS< 40 μg) greater than 200 μg/m^3, increased risk of hospitalization 1.33 fold in patients with COPD, and exposure to high levels of PM resulting in a 11% increase in the incidence of hospitalization.[18] Asthma is a well-recognized respiratory disease that can be triggered by air pollution. PM can also exacerbate asthma symptoms, and may relate to the development of asthma.[19] Past studies in Turkey support these findings.[20, 21] In this study, we found that for every 10 μg/m^3 increase in PM 10 there was a 3.9% increase in COPD in patients >65 years old and a 2.13% increase in asthma.

Examination of the effects of daily mean concentrations of contaminants on both hospital admissions and daily mortality rates involves examining daily data, pulled from at least two years of exposure. Meteorological data act as confounding factors when examining the effects of air pollution. Beginning in the 1990s, researchers examined the effects of daily and 0–4 daily mean concentrations of pollutants on daily mortality or hospitalization using the time series analysis method. A comprehensive study out of the United States of Americaon115 million patients with COPD, heart failure, cerebrovascular disease and chest diseases revealed an association between daily PM 2.5 concentrations and hospital admissions in 204 residential areas. Hospital admissions for cardiac insufficiency increased by 1.23% when PM 2.5 concentrations increased by 10 μg/m^3.[22] A 2013 study of hospital admissions in 25% of the cities in Italy found increases in respiratory diseases due to PM 10 (0.75%) and PM 2.5 concentrations (1.23%) of 10 μg/m^3.[14] In another study conducted with this method,[23] found that by correlating heart and respiratory tract diseases with gas and particulate matter concentrations in seven cities in Canada, communities with high levels of PM 10 and PM 2.5 had a 3–4 fold increase in risk of hospitalization.[23] In the present study, for every 10 μg/m^3 increase in PM 10 there was a 2.88% increased frequency of respiratory complaints for males and a 2.57% increase in females.

In a study conducted in Balikesir, there was a strong correlation between PM 10 level and hospital admissions for all disease classes and age groups. An increase of up to 10 μg/m^3 in PM 10 concentrations variably increases risk by 0.9% in patients with respiratory diseases such as asthma, acute bronchitis, chronic bronchitis and COPD.[24] Children are disproportionately affected by exposure to air pollution.

In boys, the risk of asthma was more common. Increases in admissions secondary to COPD, pneumonia, lower respiratory tract disease, and chronic bronchitis were more pronounced in adults. We estimate the increase in hospital admissions for PM 10 (10 μg/m^3 increase) as 14 children and seven adults for every 1.000 people in the city. In our study, there was a high increase in the number of respiratory-related hospital admissions, totaling 26 out of every 1000 people.

Conclusion

This study strengthens the argument that air pollution increases respiratory system complaints and hospital ad-

missions. We identified the group at highest risk as those aged 15–34 years, and over 65 years. Among the diagnostic groups, patients with acute bronchitis had the highest increase in hospital admissions due to air pollution. In Erzincan, there was a 2.57% increase in the rate of hospital admissions due to air pollution in 2015–2016, accounting for 2.47% of the total health-related expenditures for this group. Notably, this figure covers only direct costs and in fact the total cost is likely much higher. Attempts should be made to prevent the acute and chronic effects of air pollutants by implementing measures to improve air quality in order to reduce associated increases in morbidity and mortality while minimizing health-related expenditures for the treatment of respiratory conditions.

Disclosures

Ethics Committee Approval: Since our study is retrospective, data have been used with the approval of unit management.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – E.U., E.B.; Design – E.U., S.A.; Supervision – S.A.; Materials – E.U., E.B.; Data collection &/or processing – M.A.; Analysis and/or interpretation – E.U., A.Ç., S.A., L.H.T.; Literature search – M.F.; Writing – E.U., A.S.; Critical review – E.U., A.S.

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