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Original Article

Fine Particle Air Pollution (PM 2.5) and Cardiovascular Hospitalization in Isfahan in 2012: CAPACITY Study

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ABSTRACT

Background: This study aimed to evaluate the relationship between exposure to $PM_{2.5}$ and the number of hospital admissions due to cardiovascular diseases.

Methods: The present time-series, case-crossover study is a part of the CAPACITY study on patients admitted to 15 hospitals in the Iranian city of Isfahan because of cardiovascular diseases in 2012. $PM_{2.5}$ concentrations were calculated in air pollution monitoring stations and divided into 3 groups of good or moderate, unhealthy for sensitive people, and unhealthy or hazardous. The relationship between the number of admissions and fine particle concentrations was assessed.

Results: This study evaluated 15752 participants at a mean age of 59 ± 19.4 years. Men accounted for 52.6% (n = 8282) of the study population. The mean concentration of fine particles was 53.77 ± 29.65 micrometers. In most days of the year, the concentration of $PM_{2.5}$ was at an unhealthy level for sensitive people. Poisson regression analysis showed a significant correlation between the number of hospital admissions due to cardiovascular diseases and ischemic heart diseases and fine particle concentrations in the unhealthy level for sensitive people (P = 0.001, P = 0.001, and P = 0.002). There was a significant correlation between $PM_{2.5}$ concentrations and the number of admissions due to conductive heart diseases and heart blocks in unhealthy or hazardous levels (P = 0.02 and P = 0.04).

Conclusions: The number of hospital admissions due to cardiovascular diseases can increase during air pollution, especially when the concentrations of $PM_{2.5}$ are elevated. ***(Iranian Heart Journal 2020; 21(1): 75-81)***

KEYWORDS: Fine particle, Cardiovascular diseases, Air pollution

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Air pollution in cities is one of the main health problems worldwide and is defined as the presence of harmful or excessive quantities of substances in the earth's atmosphere. [1] Air pollution substances include coarse particles (PM_{10}: 2.5–10 micrometers), fine particles ($PM_{2.5}$: < 2.5 micrometers), and ultra$PM_{2.5}$ ($PM_{0.1}$: < 0.1 micrometers). [2]

There is evidence indicating a remarkable correlation between air pollution and adverse cardiovascular events. [3-6] Epidemiological investigations have revealed an increase in the level of the incidence of arrhythmias, the duration of hospitalization, and mortality and morbidity after long-term exposure to polluted air. [7] Previous research has also demonstrated that the inhalation of air pollutants may increase platelet counts and activity, systemic inflammation, and the level of oxidative stress, which can lead to vascular damage, atherosclerosis, and autonomic dysfunction. [8] In a case-crossover study, an increased level of $PM_{2.5}$ for 2 hours increased the risk of myocardial infarction in 48% of cases. [9] Inhalation of air polluted substances can decrease heart rates and increase blood pressure. [10]

Studies on the effects of air pollution on cardiovascular diseases are divided into 2 groups: short-term investigations evaluating the effects of acute exposure with polluted air on health and long-term investigation (eg, cohort studies) assessing the correlation between air pollution and its chronic effects on increasing cardiovascular disease risks. Both of these studies have revealed the significant relationship between excessive exposure to polluted air and increased mortality rates due to cardiovascular diseases. [10,11]

Cardiovascular diseases are prevalent in Iran, and there is a well-known relationship between air pollution and cardiovascular diseases. [6,12] Isfahan is the third most populated province of Iran with a population of 2 240 249 in 2016. Isfahan is a great industrial city featuring several different industrial factories. [13] Indeed, the city is surrounded by thermal power plants, steel companies, cement plants, and oil refineries. [14] To assess air pollution in Isfahan, we sought to evaluate patients in the majority of hospitals in Isfahan. $PM_{2.5}$ is an aqueous ionic composition in the air that is used for estimating organic masses in meteorology. [15] Previous studies that have evaluated the correlation between air pollution and cardiovascular diseases had small sample sizes or evaluated the effects of specific particles on cardiovascular diseases. In the present study, we aimed to evaluate the relationship between exposure to $PM_{2.5}$ and the number of hospital admissions due to cardiovascular diseases.

METHODS

The present retrospective time-series case-crossover study was conducted on the correlation between air pollution and cardiovascular and respiratory diseases (air pollution and cardiovascular and respiratory diseases: rationale and methodology of the CAPACITY study). The CAPASITY study is a comprehensive study on the correlation between the presence of air pollutants and hospitalization rates due to cardiovascular and pulmonary diseases from 2010 to 2012. [16] The current study evaluated the findings of the year 2012 because $PM_{2.5}$ was evaluated only during this year. The study population consisted of patients admitted to 15 hospitals of the Iranian city of Isfahan (Sina, Shariati, Sepahan, Askarieh, Amin, Chamran, Sadoughi, Gharazi, Khanevadeh,

Noor, Alzahra, Kashani, Amiralmomenin, Isabne Maryam, and Feiz) because of cardiovascular diseases in 2012. Participants were selected via nonrandom convenience sampling methods according to hospital records. The inclusion criteria were as follows 1) patients with the diagnosis of cardiovascular diseases based on the International Classification of Diseases -10 (ICD-10) criteria (International Classification of Diseases, I00-I99 for cardiovascular diseases) and 2) residence in Isfahan city based on addresses in the patients' medical records. Patients with incomplete clinical and paraclinical data were excluded from this study. The study protocol was approved by the Regional Bioethics Committee of Isfahan University of Medical Sciences (IUMS).

The medical records of patients with cardiovascular disease diagnoses were taken from hospital archives. Cardiovascular diseases were comprised of hypertension, ischemic heart diseases, conductive heart diseases and heart blocks, heart failure, and cerebrovascular disease with ICD-10 (I10-I15), (I20-I25), (I44-I46), (I50), and (I60-I69), respectively. The data extracted from each medical record included demographic data, as well as diagnostic and therapeutic data. These data were extracted from paper medical records or the Hospital Information System (HIS). About 8 hospitals had HIS and 7 hospitals had paper medical records. About 10% of the medical records were evaluated by cardiologists to assess the diagnosis of the patients for the quality control of the study.

Data regarding air pollution with $PM_{2.5}$, air temperature, and air humidity were extracted from the archives of the weather and pollution monitoring stations in Isfahan from 2011 to 2012. Hourly records of air pollutants were extracted from the air pollution monitoring station archives and managed in Microsoft Excel files by the lab experts of Isfahan's Department of Environment. The data on $PM_{2.5}$ were recorded only in the year 2010. First, the average 24-hour level of each station and then the mean level of the $PM_{2.5}$ concentration in Isfahan were calculated. All the files related to 24-hour levels of different stations and the whole Isfahan city were finally used to evaluate the $PM_{2.5}$ concentrations. The $PM_{2.5}$ concentrations were divided into 3 groups of good or moderate, unhealthy for sensitive people, and unhealthy or hazardous. [17]

Time-series and case-crossover methods were simultaneously applied for the data analysis of all the objectives of the CAPACITY study. The data analyses were conducted using R version 3.2.3. A confidence interval (CI) of 95% was considered in both Poisson and conditional regression methods. The Poisson regression analysis was used to investigate the effect of the $PM_{2.5}$ concentration on per day admission due to cardiovascular diseases, and the first level of concentration classification (good or moderate) was considered the reference level. A 2-sided α level of 0.05 was used to assess statistical significance.

RESULTS

The current study evaluated 15752 hospital patients at a mean age of 59 ± 19.4 years. Men represented 52.6% (n = 8282) of the study population. The mean wind speed, temperature, and humidity were 5.46 ± 2.63 m/s, 60 ± 19.06 °F, and 25.56 ± 8.87%, respectively. The distributions of the cardiovascular diseases were as follows: ischemic heart diseases (60.5%, n = 7580), hypertension (15.8%, n = 1982), cerebrovascular disease (12.3%, n = 1535), heart failure (7.8%, n = 982), and conductive heart diseases and heart blocks (3.6%, n = 447).

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The mean concentration of $PM_{2.5}$ was 53.77 ± 29.65 micrometers. The concentration of $PM_{2.5}$ in the 1-year period was in the classification of good or moderate, unhealthy for sensitive people, and unhealthy or hazardous in 102 (28%), 187 (51.4%), and 75 (20.6%) days in the year, respectively.

The one-way ANOVA analysis did not show any significant correlation between the concentrations of $PM_{2.5}$ and the number of hospital admissions due to different cardiovascular diseases (P = 0.68) (Table 1).

Table 1. Number of hospital admissions due to cardiovascular diseases in the different concentrations of $PM_{2.5}$

Cardiovascular disease	$PM_{2.5}$ concentration			*P* value
	Good or Moderate Number (%)	Unhealthy for Sensitive People Number (%)	Unhealthy or Hazardous Number (%)	
Hypertension	522(26.4)	1047(53.0)	408(20.6)	0.683
Ischemic heart diseases	2010(26.6)	4058(53.7)	1491(19.7)	
Conductive heart diseases and heart blocks	122(27.4)	227(50.9)	97(21.7)	
Heart failure	271(27.6)	522(53.2)	188(19.2)	
Cerebrovascular diseases	438(28.6)	788(51.4)	306(20.0)	

The Poisson regression analysis had 3 models, as follows: a primary model without considering confounding variables; an analysis considering age and gender; and an analysis considering age, gender, and weather variables (wind speed, humidity, etc). This analysis showed a significant correlation between the number of per day admissions due to all cardiovascular diseases and $PM_{2.5}$ concentrations in the level of unhealthy for sensitive people in the 3 models (P = 0.001, P = 0.001, and P = 0.002). There was a statistically remarkable correlation between the $PM_{2.5}$ concentrations and the number of per day admissions due to ischemic heart diseases in the level of unhealthy for sensitive people in the 3 models of analysis ($P < 0.001$, $P < 0.001$, and $P < 0.01$). There was a nonsignificant correlation between the $PM_{2.5}$ concentrations and the number of admissions due to conductive heart diseases and heart blocks in the first model ($P > 0.05$), but this correlation was significant in the level of unhealthy or hazardous in the other 2 models (P = 0.02 and P = 0.04). There was no significant correlation between the $PM_{2.5}$ concentrations and the number of per day admissions due to hypertension, cerebrovascular diseases, and heart failure ($P > 0.05$) (Table 2).

Table 2. Poisson regression analysis for evaluating the correlation between the number of admissions and the type of cardiovascular diseases

Cardiovascular Disease	$PM_{2.5}$ concentration	Primary Model		Second Model		Third Model	
		IRR(95%CI)	*P* value	IRR(95%CI)	*P* value	IRR(95%CI)	*P* value
Hypertension	good or moderate	1		1		1	
	unhealthy for sensitive people	1.09 (0.98,1.22)	0.09	(0.95,1.22) 1.07	0.24	1.08 (0.94,1.24)	0.26
	unhealthy or hazardous	1.06 (0.93,1.21)	0.35	1.00 (0.85,1.17)	0.98	0.98 (0.83,1.16)	0.80
Ischemic heart diseases	good or moderate	1		1		1	
	unhealthy for sensitive people	1.10 (1.04,1.16)	<0.001	1.11 (1.05,1.17)	<0.001	1.08 (1.02,1.14)	0.01
	unhealthy or hazardous	1.01 (0.94,1.08)	0.82	1.00 (0.94,1.07)	0.93	0.99 (0.93,1.07)	0.95
Conductive heart diseases and heart blocks	good or moderate	1		1		1	
	unhealthy for sensitive people	1.01 (0.81,1.26)	0.89	1.31 (0.76,2.26)	0.33	1.29 (0.73,2.33)	0.38
	unhealthy or hazardous	1.08 (0.83,1.41)	0.57	2.03 (1.13,3.66)	0.02	1.94 (1.03,3.63)	0.04
Heart failure	good or moderate	1		1		1	
	unhealthy for sensitive people	1.05 (0.91,1.22)	0.51	1.15 (0.91,1.44)	0.25	1.23 (0.96,1.57)	0.10
	unhealthy or hazardous	0.94 (0.78,1.14)	0.54	1.06 (0.79,1.43)	0.68	1.15 (0.84,1.56)	0.39
Cerebrovascular diseases	good or moderate	1		1		1	
	unhealthy for sensitive people	0.98 (0.87,1.10)	0.75	1.03 (0.89,1.19)	0.71	1.03 (0.87,1.20)	0.76
	unhealthy or hazardous	0.95 (0.82,1.10)	0.49	1.03 (0.86,1.25)	0.72	1.04 (0.85,1.26)	0.73
All types of cardiovascular diseases	good or moderate	1		1		1	
	unhealthy for sensitive people	1.07 (1.03,1.12)	<0.001	1.07 (1.03,1.12)	0.001	1.06 (1.02,1.11)	0.005
	unhealthy or hazardous	1.01 (0.96,1.06)	0.79	1.00 (0.95,1.05)	0.94	1.00 (0.94,1.06)	0.94

DISCUSSION

The present study evaluated the correlation between $PM_{2.5}$ concentrations and the number of per day admissions due to different cardiovascular diseases in the year 2012. We found a significant correlation between $PM_{2.5}$ concentrations and the number of hospital admissions due to all cardiovascular diseases, especially ischemic heart diseases, in the level of unhealthy for sensitive people. There was also a significant correlation between the number of hospital admissions due to conductive heart diseases and heart blocks in the level of unhealthy or hazardous $PM_{2.5}$ concentrations.

Studies have demonstrated that more exposure to air pollution can increase acute cardiovascular events and exacerbate chronic cardiovascular diseases. [8] Researchers have also evaluated the relationship between air pollution and cardiovascular diseases. Dominici et al [18] evaluated the relationship between air $PM_{2.5}$ concentrations and the number of hospitalization due to cardiovascular and pulmonary diseases and revealed that an increase of 10 $\mu g/m^3$ in $PM_{2.5}$ daily concentrations could cause a 1.3% increase in the number of hospitalization because of heart failure. Another study on 7 cities in the United States of America reported that a rise of 10 $\mu g/m^3$ in air pollution in a day could cause a 0.7% increase in the number of hospitalization due to congestive heart diseases. [19] Another investigation showed a significant increase in coronary artery

disease complications after short-term exposure to $PM_{2.5}$ air pollution. [20] A study on a sample of the Iranian population revealed an annual mortality rate of 4.64% owing to air pollutants. [21]

Air pollution can increase the release of pro-oxidative and pro-inflammatory mediators from the lungs to the circulation and also cause autonomic nerve systemic imbalances. It has direct effects on the heart and triggers the entrance of fine and ultra$PM_{2.5}$ to the systemic circulation. Oxidative stress induction by these particles can lead to impairment in coagulation and thrombosis. [22] Air pollution also increases heart rate, decreases heart rate variability, and causes endothelial dysfunction, arterial vasoconstriction, apoptosis, and hypertension. Acute exposure to air pollution can cause plaque instability, affecting the risk factors of cardiovascular events, and chronic exposure to air pollution causes atherosclerosis and hypertension. [8]

In the current study, the relationship between the number of hospital admissions due to cardiovascular diseases and $PM_{2.5}$ in the level of unhealthy for sensitive people is likely due to the fact that the number of days with this level of air pollution was more than that of other situations in the year 2012. The CAPACITY study showed that the mean annual pollutants in the years 2010 and 2011 were higher than the standard levels and the mean concentrations of ozone, carbon monoxide, and PM_{10} were lower in the year 2011 than in the year 2010, while the mean levels of sulfur dioxide and nitrogen dioxide were higher. [16]

Our study had strengths and limitations. One of the strengths of this study is its large sample size, allowing the generalization of the results to the general population. Another strong point of this study is that we evaluated each type of cardiovascular diseases separately. Nonetheless, one of the limitations of this study is that we considered only $PM_{2.5}$ as air pollution; if we had taken into account all 3 types of particles (coarse, fine, and ultrafine) and evaluated the relationship between all these particles and the number of hospital admissions due to cardiovascular diseases, we might have obtained more reliable results concerning this relationship. In this study, we did not distinguish between new cases of cardiovascular diseases and the exacerbation of previous cardiovascular diseases. Future studies should take into consideration this situation and evaluate the past medical history of patients admitted during air pollution because of cardiovascular diseases.

In conclusion, the number of hospital admissions due to cardiovascular diseases can increase during air pollution, especially when the concentrations of $PM_{2.5}$ have risen.

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