



Association between ambient fine particulate matter with blood pressure levels among Iranian individuals admitted for cardiac and respiratory diseases: Data from CAPACITY study

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Original Article

Abstract

BACKGROUND: The relation between air pollution and cardiovascular diseases (CVDs) risk factors, especially blood pressure (BP) levels, has been less frequently assessed. The aim of this study was evaluating the association between air pollutants of less than 2.5 μm [particulate matter (PM_{2.5})] and BP indices among individuals admitted with CVDs and pulmonary diseases.

METHODS: This cross-sectional study was in context of air pollution associated with hospitalization and mortality of CVDs and respiratory diseases (CAPACITY) study. Data of 792 Iranian patients referring to two hospitals in Isfahan, Iran, for cardiovascular or respiratory problems from March 2011 to March 2012 were used for analysis. BP indices including systolic BP (SBP), diastolic BP (DBP), and mean arterial pressure (MAP) were obtained from patients' medical forms and mean PM_{2.5} concentrations during 24 hours prior to admission of each patient were obtained from Isfahan Department of Environment (DOE).

RESULTS: Mean \pm standard deviation (SD) of participants' age were 62.5 \pm 15.9 years. All BP indices on admission were significantly higher in women compared with men. Adjustment of all potential confounders including age, sex, temperature, wind speed, and dew point revealed that increasing one quartile in PM_{2.5} concentrations had been associated with 1.98 mmHg raising in SBP at the time of admission [95% confidence interval (CI) = 0.41-3.54, P = 0.010]. Women with cardiac diseases had higher all BP indices with increased PM_{2.5} concentration [SBP: β : 4.30, 95% CI = 0.90-7.70, P = 0.010; DBP: β : 1.89, 95% CI = 0.09-3.69, P = 0.040; MAP: β : 3.09, 95% CI = 0.68-5.51, P = 0.010, respectively].

CONCLUSION: Our findings suggest that increasing PM_{2.5} concentration has been positively associated with raising SBP in total population and all BP indices among women with cardiac problems at admission time. Several comprehensive studies are required for confirming these relations.

Keywords: Particulate Matter; Blood Pressure; Air Pollutants; Air Pollution

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Introduction

Several studies have proved the positive relation between blood pressure (BP) status and incidence of debilitating diseases including myocardial infarction (MI), heart failure (HF), stroke, sudden death, and renal problems.¹⁻³ Thus, appropriate management of abnormal BP levels would be pivotal in declining aforementioned life-threatening disorders. Although most healthcare policymakers recognize efficacious factors contributing in development of hypertension (HTN), air pollution inducing cardiovascular diseases (CVDs) is one of them.⁴ Due to urbanization of countries, contaminated air must be considered as one of the inevitable health risk factors among nations. It has been predicted that this factor is the causal agent of more than one million premature deaths worldwide.⁵ Multiple studies have suggested the influence of air pollution on mortality due to cardiac and pulmonary diseases.⁶⁻⁸ Moreover, acute confrontation with polluted air has been reported to be associated with increased cardiovascular problems including HTN, arrhythmia, HF worsening, and atherosclerosis in addition to chronically-induced deep vein thrombosis (DVT) and cardiac atherosclerosis.⁹⁻¹³ For instance, Yang et al. recruited 24845 individuals in order to assess the association of exposure to air pollution with HTN and found that increasing 10 $\mu\text{g}/\text{m}^3$ in particulate matter (PM) of less than 1 μm was associated with raised systolic BP (SBP) and diastolic BP (DBP) and participants confronting pollutants had 5% increased odds of getting HTN. This situation has been suggested to be positively associated with increasing admission rates for HTN.¹⁴ Air pollutants contain different size and combination of suspended solid or liquid particles in composition with air gases like ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Based on their sizes, they are categorized to coarse (2.5-10 μm), fine (< 2.5 μm), and ultra-fine (< 0.1 μm) particles which could be considered as a useful air pollution index according to their vast toxic effects.^{15,16}

In this article, we aimed to evaluate the relation

between air pollutants of less than 2.5 μm with mean BP levels among Iranian hospitalized patients due to cardiac or respiratory diseases on the first day of admission.

Materials and Methods

Data of this cross-sectional research were in context of air pollution associated with hospitalization and mortality of cardiovascular and respiratory diseases (CAPACITY study) in which its exact methodology has been described in details elsewhere.¹⁷ In summary, the main aim of CAPACITY study was evaluating the relation of air pollutants including PM, NO_2 , CO, O_3 , and SO_2 with hospitalization due to CVDs or pulmonary diseases. From March 2011 till March 2012, any patient living in Isfahan, Iran, referred to two Isfahan governmental hospitals (Noor and Chamran Hospitals) for either cardiovascular or respiratory problems based on International Classification of Diseases, 10th Revision (ICD-10) including I00-I99 and J00-J99, respectively, had been qualified for enrollment in our study. Data of participants were obtained from their medical profiles in hospital registry system. Incompleteness of medical records, especially age, gender, or BP levels and residing of participants elsewhere rather than Isfahan were defined as exclusion criteria. A total of 1017 patients were hospitalized during our pre-defined period and data of 792 patients were available for analysis at last. This study was approved by the Ethics Committee of Isfahan University of Medical Sciences, Isfahan (No. 396991).

Demographic data including age, gender, and BP indices like SBP, DBP, and mean arterial pressure (MAP) at the time of admission were collected through each participant's medical form. Data on mean $\text{PM}_{2.5}$ concentration ($\mu\text{g}/\text{m}^3$), temperature (Fahrenheit), wind speed (mile/hour), and dew point (%) during the 24 hours prior to patients' admission were collected from Isfahan Department of Environment (DOE) information extracted from CAPACITY study. We further categorized the participants based on the presence/absence of cardiac or respiratory diseases.

Continuous and categorical variables were reported as mean \pm standard deviation (SD) and frequency (%), respectively. Independent t-test was used for assessing the difference of continuous variables between genders. Assumptions for this test including normality and equality of variances were checked by Kolmogorov-Smirnov test (K-S test) and Levene's test, respectively. Furthermore, the association between BP indices (SBP, DBP, and

Table 1. Distribution of blood pressure (BP) indices in study population on admission date

Patients	BP index (mmHg)	Total	Women	Men	P*
Total	SBP	129.0 ± 24.0	130.8 ± 25.7	126.7 ± 21.7	0.020
	DBP	78.0 ± 13.0	79.1 ± 13.6	77.9 ± 12.1	0.190
	MAP	103.6 ± 16.9	105.0 ± 18.4	102.4 ± 15.9	0.030
With cardiac problems	SBP	129.3 ± 24.4	132.7 ± 27.3	126.6 ± 21.5	0.009
	DBP	78.5 ± 13.2	79.5 ± 14.4	77.7 ± 12.1	0.140
	MAP	104.0 ± 17.6	106.1 ± 19.4	102.3 ± 15.7	0.020
With respiratory problems	SBP	127.5 ± 22.1	127.0 ± 22.0	127.9 ± 22.3	0.740
	DBP	78.7 ± 11.9	77.7 ± 11.8	79.4 ± 12.0	0.270
	MAP	103.2 ± 15.9	102.3 ± 15.9	103.8 ± 15.9	0.440

Data are presented as mean ± standard deviation (SD)

*P-values resulted from independent t-test

BP: Blood pressure; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure

MAP) and PM_{2.5} concentrations during the 24 hours prior to patient's admission was assessed using different linear regression models according to each quartile increment in PM_{2.5}. First, we created a categorical variable by using PM_{2.5} quartiles and entered this variable in models as a single one. Assumptions for linear regression models including normality, collinearity, and equality of variances were assessed with K-S test, variance inflation factor (VIF) estimating, and graphical checking, respectively. Moreover, several models were also implemented. The model 1 was adjusted for age and sex. Further adjustment for temperature, wind speed, and dew point was done in model 2. These models were assessed among total population and by each disease type (either cardiac or respiratory). All analyses were done utilizing SPSS software (version 21.0, IBM Corporation, Armonk, NY, USA) and P-values less than 0.05 were considered statistically significant.

Results

The mean age of total population and male and female participants were 62.50 ± 15.90 years, 62.10

± 16.01 years, and 62.91 ± 15.81 years, respectively. Among 792 studied patients, 509 and 283 patients were hospitalized for cardiac problems and respiratory problems, respectively. Table 1 provides BP indices data including SBP, DBP, and MAP during admission time. Women had significantly higher means of SBP and MAP compared to men (130.8 ± 25.7 mmHg vs. 126.7 ± 21.7 mmHg, P = 0.020 and 105.0 ± 18.4 mmHg vs. 102.4 ± 15.9 mmHg, P = 0.030, respectively), but this relation was insignificant in terms of DBP. Disease stratified analysis showed that women suffering from cardiac diseases had remarkably higher means of SBP and MAP rather than men (132.7 ± 27.3 mmHg vs. 126.6 ± 21.5 mmHg, P = 0.009 and 106.1 ± 19.4 mmHg vs. 102.3 ± 15.7 mmHg, P = 0.020, respectively). PM_{2.5} concentrations, temperature, wind speed, and dew point in 24 hours before patient admission were 50.7 ± 21.3 µg/m³, 58.4 ± 19.4 Fahrenheit, 28.4 ± 9.2 mile/hour, and 5.3 ± 2.6 percent, respectively.

Table 2 showed relation between SBP, DBP, and MAP with PM_{2.5} on admission time according to disease subtypes.

Table 2. Association between blood pressure (BP) indices and particulate matter (PM_{2.5}) quartiles according to disease subtypes

Participants	Model	SBP [β (95% CI)]	P	DBP [β (95% CI)]	P	MAP [β (95% CI)]	P
Total	Crude	1.35 (-0.09, 2.80)	0.060	0.31 (-0.48, 1.09)	0.440	0.79 (-0.26, 1.84)	0.130
	Model 1	1.51 (0.07, 2.94)	0.040	0.35 (-0.43, 1.14)	0.370	0.89 (-0.15, 1.93)	0.090
	Model 2	1.98 (0.41, 3.54)	0.010	0.45 (-0.40, 1.29)	0.300	1.09 (-0.02, 2.21)	0.050
With cardiac problems	Crude	1.77 (-0.15, 3.68)	0.070	0.94 (-0.10, 1.97)	0.080	1.29 (-0.09, 2.67)	0.070
	Model 1	1.81 (-0.08, 3.69)	0.060	0.94 (-0.08, 1.96)	0.070	1.30 (-0.05, 2.66)	0.060
	Model 2	2.63 (0.61, 4.64)	0.010	1.00 (-0.10, 2.10)	0.080	1.74 (0.29, 3.20)	0.020
With respiratory problems	Crude	0.72 (-1.73, 3.17)	0.560	-1.05 (-2.37, 0.27)	0.120	-0.16 (-1.94, 1.61)	0.860
	Model 1	1.12 (-1.35, 3.59)	0.370	-1.02 (-2.36, 0.32)	0.130	0.05 (-1.74, 1.84)	0.960
	Model 2	0.68 (-2.04, 3.39)	0.630	-1.14 (-2.62, 0.34)	0.130	-0.25 (-2.22, 1.72)	0.800

SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; CI: Confidence interval

Model 1: Adjusted for age and sex

Model 2: Adjusted for age, sex, temperature, wind speed, and dew point

Although there was no significant relation between SBP and PM_{2.5} concentration in crude model ($P = 0.060$), adjusted model revealed that each quartile increasing in PM_{2.5} was associated with raising 1.98 mmHg of SBP in total population [95% confidence interval (CI) = 0.41-3.54, $P = 0.010$]. No significant association was found in terms of DBP or MAP among total participants. Further analysis stratified by cardiac or respiratory problems showed that each quartile increment in PM_{2.5} concentration was associated with 2.63 (95% CI = 0.61-4.64, $P = 0.010$) and 1.74 (95% CI = 0.29-3.20, $P = 0.020$) mmHg increase in SBP and MAP among individuals admitted for cardiac diseases, respectively. Patients with pulmonary diseases showed no significant relation between SBP, DBP, and MAP with PM_{2.5} concentrations at the time of admission.

Stratified gender analysis, as depicted in table 3, showed that although there was no remarkable relation in each sex category, increasing PM_{2.5} was associated with heightened SBP, DBP, and MAP among women suffering from cardiac diseases (β : 4.30, 95% CI = 0.90-7.70, $P = 0.010$; β : 1.89, 95% CI = 0.09-3.69, $P = 0.040$; β : 3.09, 95% CI = 0.68-5.51, $P = 0.010$, respectively). On the other hand, increasing PM_{2.5} concentration was associated with decreased levels of DBP among women with respiratory problems (β : -2.45, 95% CI = -4.65, -0.26, $P = 0.030$).

There was no statistically significant relationship between SBP, DBP, and MAP with PM_{2.5} concentration among male patients with either cardiac or pulmonary disorders.

Discussion

The aim of the current study was evaluating the relationship between PM_{2.5} with BP indices on the first day of patient's admission due to cardiac or pulmonary diseases. Our findings suggested that after adjustment for potential confounding variables, a positive association was found in terms of SBP at admission time with increasing PM_{2.5} concentration, but this relation was insignificant in terms of DBP or MAP. Furthermore, this increasing pattern was also observed among women admitted for cardiac diseases with all BP indices. Since air pollution has been associated with increasing CVDs risk factors, several interventions must have been taken in order to reduce this concerning prevalence. In agreement with our findings, several studies suggested a positive association between PM_{2.5} concentration and BP

levels, especially among majority of population residing in industrial countries.¹⁸⁻²⁰

In this study, women had higher means of SBP and MAP compared to men which was consistent with Chen et al.'s study showing a significant relationship between PM_{2.5} and fatal congestive heart disease observed just in women.²¹ Although the exact pathophysiological mechanism for this difference has not been announced, Kim and Hu postulated that particle deposition was greater and more localized in women's lung compared to men.²² On the other hand, results of Sorensen et al.'s study revealed that women were more sensitive to toxicological effects of air pollutants compared with men due to their lower red blood cell (RBC) content.²³

Several studies performed in different countries with variable age groups have also demonstrated the effectiveness of acute confrontation with contaminated air in CVDs mortality and increased BP ranges.²⁴⁻²⁶ Results of a cross-sectional study done on 5011 Canadian individuals revealed that raising 4.5 $\mu\text{g}/\text{m}^3$ of PM_{2.5} had been associated with significant heightening of both SBP and DBP.²⁷ Our findings were insignificant in terms of DBP or MAP. One possible explanation might be due to composition of air pollutants with different characteristics. Likewise, Dai et al. performed a study on 718 elderly men in order to find which PM_{2.5} components had been associated with increasing BP levels. Their outcomes revealed that nickel was associated with raising of both indices of BP including SBP and DBP (2.48 mmHg, 95% CI = 1.45-3.50 and 2.22 mmHg, 95% CI = 1.69-2.75, respectively).²⁸ Furthermore, two meta-analysis studies reported that in spite of positive association found between PM_{2.5} and SBP, insignificant relation was declared in terms of DBP.^{29,30} Moreover, 130 children aged 6-12 years were selected for enrollment in a study done by Pieters et al. Their BP levels had been measured during two times in spring and fall and their associations with PM measured in playground were evaluated. Finally, they found that there was not any significant relation in terms of PM_{2.5} with neither SBP nor DBP.³¹

Quite large sample size and precise assessments in a relatively more ventilated location were some advantages of our study. By the way, some limitations were attributable for current research. Data collection was purely from medical forms. Inability to consider the distance of each participant's address from air pollution monitoring centers was another disadvantage of this study which might affect the generalization of our findings.

Table 3. Association between blood pressure (BP) indices and particulate matter (PM_{2.5}) quartiles according to disease subtypes

Participants		Model	SBP [β (95% CI)]	P	DBP [β (95% CI)]	P	MAP [β (95% CI)]	P
Men	Total	Crude	0.990 (-0.780, 2.770)	0.270	0.120 (-0.880, 1.110)	0.820	0.480 (-0.810, 1.780)	0.460
		Model 1	1.160 (-0.610, 2.920)	0.200	0.200 (-0.800, 1.190)	0.700	0.600 (-0.680, 1.890)	0.360
		Model 2	1.440 (-0.480, 3.360)	0.140	0.330 (-0.740, 1.460)	0.540	0.790 (-0.610, 2.130)	0.270
	With cardiac problems	Crude	0.300 (-1.970, 2.570)	0.800	-0.060 (-1.340, 1.220)	0.920	-0.003 (-1.670, 1.660)	0.990
		Model 1	0.240 (-2.020, 2.500)	0.840	-0.090 (-1.360, 1.190)	0.890	-0.050 (-1.700, 1.600)	0.950
		Model 2	1.180 (-1.260, 3.620)	0.340	0.200 (-1.170, 1.580)	0.770	0.540 (-1.240, 2.330)	0.550
	With respiratory problems	Crude	2.150 (-1.020, 5.310)	0.180	0.040 (-1.680, 1.760)	0.960	1.080 (-1.200, 3.370)	0.350
		Model 1	2.900 (-0.340, 6.150)	0.080	1.550 (-0.800, 3.900)	0.190	2.900 (-0.340, 6.150)	0.080
		Model 2	1.890 (-1.810, 5.590)	0.310	-0.180 (-2.210, 1.860)	0.860	0.790 (-1.890, 3.460)	0.560
Women	Total	Crude	1.970 (-0.470, 4.400)	0.110	0.580 (-0.710, 1.870)	0.380	1.280 (-0.460, 3.010)	0.150
		Model 1	1.860 (-0.540, 4.270)	0.130	0.540 (-0.750, 1.820)	0.410	1.200 (-0.510, 2.920)	0.200
		Model 2	2.190 (-0.390, 4.760)	0.090	0.570 (-0.810, 1.950)	0.420	1.390 (-0.450, 3.240)	0.140
	With cardiac problems	Crude	3.860 (0.650, 7.070)	0.020	2.270 (0.590, 3.940)	0.008	3.060 (0.780, 5.340)	0.009
		Model 1	3.690 (0.540, 6.850)	0.020	2.200 (0.540, 3.870)	0.010	2.950 (0.710, 5.190)	0.010
		Model 2	4.300 (0.900, 7.700)	0.010	1.890 (0.090, 3.690)	0.040	3.090 (0.680, 5.510)	0.010
	With respiratory problems	Crude	-1.530 (-5.450, 2.400)	0.440	-2.790 (-4.830, -0.740)	0.008	-2.130 (-4.950, 0.690)	0.140
		Model 1	-1.530 (-5.440, 2.370)	0.440	-2.790 (-4.850, -0.730)	0.008	-2.140 (-5.000, 0.680)	0.140
		Model 2	-1.130 (-5.300, 3.040)	0.590	-2.450 (-4.650, -0.260)	0.030	-1.700 (-4.730, 1.320)	0.270

SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; CI: Confidence interval

Model 1: Adjusted for age

Model 2: Adjusted for age, temperature, wind speed, and dew point

Conclusion

We found that increasing PM_{2.5} concentration has been associated with increasing SBP at the time of admission, but no significant relation was found in terms of DBP, MAP, or between genders. However, women suffering from cardiac diseases had increased all BP indices in terms of increasing PM_{2.5} concentration. Multiple comprehensive population-based studies must be conducted to prove these relations.

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Conflict of Interests

Authors have no conflict of interests.

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