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Investigation of the Relationship Between the Level of Fine Particulate Matter and Stroke Mortality Rate in Mashhad in 2014 and 2015

Sima Baridkazemi [1], Khalilollah Moeininan [1], Ali Taghipour [2], Ayat Rahmani [1] and Hamidreza Nassehinia [1,*]

[1]Department of Environmental Health Engineering, School of Health, Semnan University of Medical Sciences, Semnan, Iran
[2]Social Determinants of Health Research Center, Mashhad University of Medical Sciences, Mashhad, Iran

[*]*Corresponding author*: Department of Environmental Health Engineering, School of Health, Semnan University of Medical Sciences, Semnan, Iran. Email: hrnassehi@semums.ac.ir

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Abstract

Background: Air pollution is a major social problem, particularly in developing countries, where the rapid expansion of industries, cities, and traffic is the main cause of increased air pollution.
Objectives: This ecological study (correlation) has been conducted with the aim of analyzing the correlation between ambient fine particulate matter ($PM_{2.5}$) amount and the rate of stroke mortality in Mashhad during the years 2014 and 2015.
Methods: Data were collected from hospitals, the Monitoring Center of Environmental Pollutants, and the Bureau of Meteorology in Khorasan Razavi Province and were analyzed to evaluate the correlation.
Results: The results show that the correlation coefficient between $PM_{2.5}$ and the rate of stroke mortality in different seasons in 2014 and 2015 are 0.997 and 0.902, respectively. The correlation was stronger in 2014 and is significant at a confidence level of 0.01.
Conclusions: According to the results, the annual average concentration of $PM_{2.5}$ decreased from 29.261 ($\mu g/m^3$) in 2014 to 25.283 ($\mu g/m^3$) in 2015, and also, the annual rate of stroke mortality decreased by 4.4% in 2015.

Keywords: Air Pollution, $PM_{2.5}$, Stroke Mortality, Mashhad

1. Background

Air pollution is a major social problem, particularly in developing countries, where the rapid expansion of industries, cities, and traffic is the main cause of increased air pollution (1, 2). In general, air pollution is a mixture of several components, including particulate matter (PM), gases, organic compounds, and metals (3, 4). Epidemiological and clinical evidences show that short- and long-term exposure to outdoor air pollution causes adverse health effects and leads to an increase in mortality and various diseases, particularly cardiovascular diseases and stroke (3, 5-11). The World Health Organization (WHO) defines stroke as "rapidly developed clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than of vascular origin" (12). Stroke is the second most common cause of death and the sixth most common cause of disability worldwide (13-16). Recent studies in North America, Europe, and Asia provide evidence of the effects of environmental pollutants on stroke mortality and hospitalization. Among air pollutants, PMs are the largest cause of mortality and various diseases such as stroke. Stroke mortality contributes about 10% of all mortalities worldwide. The World Health Organization estimates that there were 15.3 million strokes worldwide in 2002, of which more than a third (5.5 million) resulted in death (3, 17, 18).

Although several studies are being conducted to prevent strokes in high-income countries, more than 85% of the strokes occur in low-income and middle-income countries (17). Epidemiological studies indicate a correlation between long-term exposures with air pollution, in particular $PM_{2.5}$, and malfunction of the central nervous system (CNS), premature deaths, heart disease, stroke, respiratory diseases, and lung cancer (19-26). Studies by Global Burden of Disease (GBD) showed that in 2010, about 2.3 million deaths (5% of total global deaths) occurred worldwide due to air pollution by $PM_{2.5}$. This pollutant is ranked as the sixth biggest risk factor for premature death (19, 27). Recent studies show that in areas with high levels of $PM_{2.5}$, increased incidence of cardiovascular mortality and stroke is reported (6, 28-30). Lee et al. in 2014 conducted a study in Korea on the relation between exposure to air pollution

and cardiovascular disease. Their results showed that $PM_{2.5}$ and PM10 had adverse health effects, such as heart disease, stroke, and high blood pressure; these health effects have a stronger correlation with $PM_{2.5}$ (31). Research studies conducted in 25 communities in America show that a 10 μg/m3 increase in $PM_{2.5}$ raises all causes of mortalities by 1.2% and stroke mortalities by 1.36% (32). In 2015 Shah et al. conducted a study on the relationship between short-term exposure to air pollution and stroke. Their findings showed that the increase in the relative risk of hospital admissions for stroke or stroke mortality was 1.011 for a 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentration (33). At present, many cities around the world face environmental problems related to air pollution (34-38). The impact of environmental factors on stroke mortality is less commonly considered. Although some studies show that air pollution is a modifiable and important risk factor (33).

2. Objectives

Due to the high air pollution in Mashhad (Iran), caused mainly by the transport and the industry sectors, this study aims to analyze the relationship between the amount of $PM_{2.5}$ and stroke mortality rate in Mashhad during 2014 and 2015.

3. Methods

3.1. Sample Size

In this study, all recorded data on 24-hour average concentration of $PM_{2.5}$ pollutant (730 data points) all patients who died of a stroke in Mashhad (475 deaths) and all data pertaining to meteorological parameters (wind speed, relative humidity, temperature, and rainfall) in 2014 and 2015 have been used.

3.2. Data Collection

The data related to the 24-hour average concentration of $PM_{2.5}$ pollutants were collected from the monitoring center for environmental pollutants in Mashhad in the format of excel files. In this center, the concentration of air pollutants is automatically measured through the air quality index (AQI) at 10 stations using the Environment S.A France device. Data of patients who died due to stroke in 2014 and 2015 in Mashhad were collected by referring hospitals, reviewing the dossiers of patients, and using questionnaires. Additionally, data on meteorological parameters were collected from the Bureau of Meteorology in Khorasan Razavi Province in the format of an excel file.

3.3. Statistical Analysis

For statistical analysis, SPSS software was used. To investigate the normal distribution of the variables, the Kolmogorov–Smirnov test was applied. Pearson correlation and linear regression were used to determine the relationship between variables and predict the dependent variable. Tables and figures were drawn through excel and GraphPad Prism software.

4. Results

The results presented in Table 1 show that the Pearson correlation coefficient between the monthly average concentration of $PM_{2.5}$ pollutant and the monthly average wind speed in 2015 is -0.624 (P = 0.03). However, there is no significant correlation between $PM_{2.5}$ concentration and other meteorological parameters (relative humidity, temperature, and rainfall).

As shown in Table 2, the investigation of the average concentration of $PM_{2.5}$ pollutants and stroke mortality rate in different seasons of 2014 and 2015 shows that the highest concentration of $PM_{2.5}$ pollutant and the highest rate of stroke mortality are observed in the autumn season. Table 3 shows the results of the Pearson's correlation between the $PM_{2.5}$ pollutant with the stroke mortality in two age groups (30 to 59 years and 60 years and older), gender, and month and season of the year in 2014 and 2015. The results show that the Pearson correlation coefficients between this pollutant and stroke mortality in different months and seasons in 2014 are 0.610 (P = 0.035) and 0.997 (P = 0.003), respectively. Moreover, the Pearson correlation between the $PM_{2.5}$ pollutant and stroke mortality in the age group of 30 - 59 years in different months in 2014 and 2015 are 0.765 (P = 0.004) and 0.628 (P = 0.029), respectively.

The correlation in different months of 2014 is stronger. Figure 1A and Figure 1B show the relation between $PM_{2.5}$ pollutant and stroke mortality in different months of 2014 and 2015. As seen in Figure 1A, in 2014, the highest concentration of $PM_{2.5}$ pollutant (42.939 ± 16.02 $\mu g/m^3$) and the highest rate of stroke mortality (30 deaths) were observed in October. Figure 1B depicts that in 2015, the highest concentrations of $PM_{2.5}$ pollutant (28.934 ± 6.42 $\mu g/m^3$ and 28.741 ± 9.76 $\mu g/m^3$, respectively) were detected in September and December. The highest rate of stroke mortality (29 deaths) was seen in December. The results of linear regression between $PM_{2.5}$ pollutant and stroke mortality in different seasons of 2014 show that the correlation between these two variables is R = 0.997.

Table 1. The Pearson Correlation Between the $PM_{2.5}$ Pollutant and Meteorological Parameters (Wind Speed, Relative Humidity, Temperature and Rainfall)

Year	Pearson Correlation Test	Wind Speed (km/h)	Temperature (°C)	Rain Fall (mm/h)	Relative Humidity (%)
2014	Sig (2-tailed)	0.381	0.696	0.217	0.654
	Pearson correlation	-0.278	0.126	-0.385	-0.145
2015	Sig (2-tailed)	0.03	0.094	0.266	0.141
	Pearson correlation	-0.624[a]	-0.505	0.349	0.451

[a] Correlation is significant at the 0.05 level (2-tailed)

Table 2. The Average Concentration of $PM_{2.5}$ Pollutant and Mortality Rate in Different Seasons in 2014 and 2015

Year	Variable	Season			
		Spring	Summer	Autumn	Winter
2014	Average concentration of $PM_{2.5}$	25.67 ± 17.16	30 ± 20.58	34.5 ± 23	25.82 ± 13.06
	Number of stroke mortality	58	63	68	59
2015	Average concentration of $PM_{2.5}$	24.08 ± 16.08	23.70 ± 14.85	26.71 ± 16.71	26.71 ± 15.68
	Number of stroke mortality	55	45	66	61

Table 3. Pearson's Correlation Between the $PM_{2.5}$ Pollutant and the Stroke Mortality in Different Age Groups, Genders, Months and Seasons in 2014 and 2015

Variable	Pearson Correlation Test	Stroke Mortality	Age		Gender	
			30 - 59	≥ 60	Female	Male
2014						
Different months	Sig (2-tailed)	0.035	0.004	0.365	0.087	0.076
	Pearson Correlation	0.610[a]	0.765[b]	0.288	0.515	0.531
Different seasons	Sig (2-tailed)	0.003	0.058	0.520	0.494	0.171
	Pearson Correlation	0.997[b]	0.942	0.480	0.506	0.829
2015						
Different months	Sig (2-tailed)	0.271	0.029	0.531	0.298	0.644
	Pearson Correlation	0.346	0.628[a]	0.201	0.328	0.149
Different seasons	Sig (2-tailed)	0.098	0.017	0.211	0.244	0.403
	Pearson Correlation	0.902	0.983[a]	0.789	0.756	0.597

[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

5. Discussion

The results of this study indicate a significant negative correlation between $PM_{2.5}$ and wind speed only in different seasons of 2015. However, there was no significant relationship between $PM_{2.5}$ concentration and other meteorological parameters. Also, Huang et al., in 2015, in Beijing and Rasheed et al., in 2015, in Pakistan observed a significant negative relationship between wind speed and $PM_{2.5}$ (39, 40). Lin et al., in an investigation of the relationship between $PM_{2.5}$ and meteorological parameters, observed that there is a negative correlation between the concentration of $PM_{2.5}$ and wind speed. Also, they observed a positive relationship between this pollutant and temperature parameter in spring and summer, but not in autumn and winter (41). While the study of Bhaskar et al. in India showed that there is a significant negative relationship between suspended particulate matter concentration and rainfall (42). Zhang et al. also investigated the relationship between different air pollutants ($PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, and O_3) and meteorological parameters in three megacities in China. Their results were similar to our study about the relationship between wind speed and $PM_{2.5}$ (43).

The findings also show that in 2014 and 2015, the daily average concentration of $PM_{2.5}$ pollutant (210 and 165 days, respectively) was higher than the standard value suggested by WHO ($> 25\ \mu g/m^3$). In 2015, there was an increase

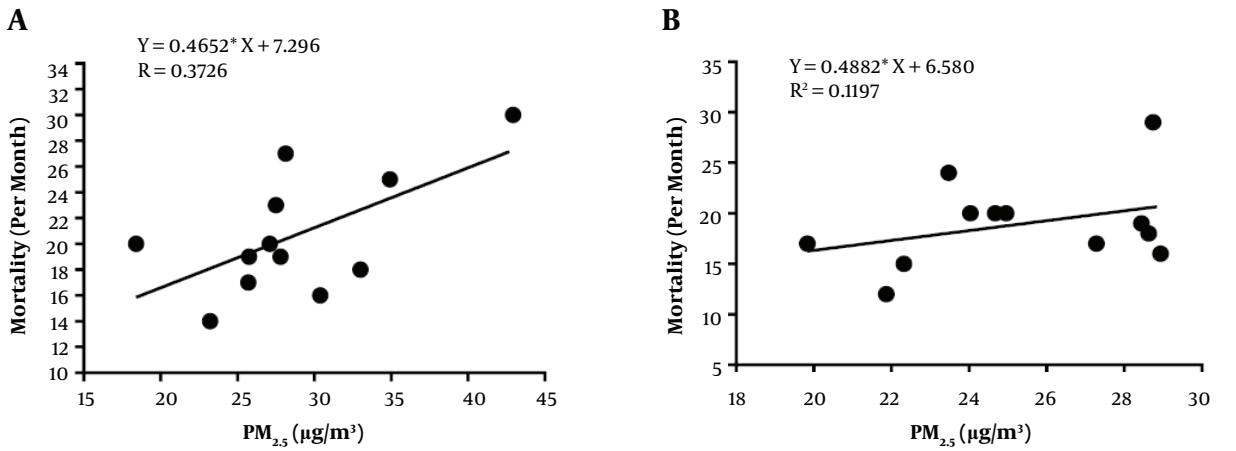

Figure 1. (A) The trend of changes in concentration of $PM_{2.5}$ and trend of changes in stroke mortality in different months in 2014 and (B) the trend of changes in concentration of $PM_{2.5}$ and trend of changes in stroke mortality in different months in 2015.

in the wind speed and a reduction in the number of days in which the average concentration of $PM_{2.5}$ was more than the WHO standard. This could reveal the role of wind in the distribution of $PM_{2.5}$. The results of our study show that the highest $PM_{2.5}$ concentration in 2014 and 2015was observed in autumn. Li et al. also studied the concentration of $PM_{2.5}$ at 11 stations in one of the Chinese cities. In addition, their results indicated that the average concentration of this pollutant was higher in autumn and winter (41).

According to the results, the annual average concentration of $PM_{2.5}$ decreased from 29.261 $\mu g/m^3$ in 2014 to 25.283 $\mu g/m^3$ in 2015. Also, the annual rate of stroke mortality decreased by 4.4% in 2015. There is a significant positive relationship between $PM_{2.5}$ pollutant and stroke mortality, especially in the age group of 30 - 59 years. In a study, Hadei et al. studied stroke deaths due to $PM_{2.5}$ exposure in ten cities of Iran. Their findings showed that Tehran, Mashhad, and Isfahan had the highest mortality rate due to stroke. The average mortality due to PM exposure in all the cities surveyed was 41 per 100000 people. The results of this study indicated the necessity of urgent actions to improve outdoor air quality in Iranian cities (44). Lin et al. investigated the relationship between ambient $PM_{2.5}$ and stroke in six low- and middle-income countries. In this study, 45625 people were studied, and information about ambient $PM_{2.5}$ levels was estimated using satellite data. The results of their study showed that the odds of stroke were 1.13 for each 10 $\mu g/m^3$ increase in $PM_{2.5}$ (45).

Pascal et al. in 2014 conducted a study on the short-term effects of particulate matter ($PM_{2.5}$, $PM_{10e2.5}$, and PM_{10}) on mortality in nine French towns. The results show a direct correlation between mortality and the concentration of PMs in the air (46). Chalbot et al., in 2014, investigated the correlation between the non-randomized process of cardiovascular disease mortality, stroke, and lung cancer and the reduction in $PM_{2.5}$ pollutant in Arkansas. Their results showed that the annual average concentration of $PM_{2.5}$ reduced from 14.5 $\mu g/m^3$ in 2000 to 11.5 $\mu g/m^3$ in 2010, causing a decrease in cardiovascular mortality, stroke, and lung cancer by 21%, 30%, and 2% respectively (47).

5.1. Conclusions

The results indicate that there is a significant positive relationship between the level of $PM_{2.5}$ pollutant and stroke mortality rate in Mashhad, especially in the age group of 30 - 59 years. Overall, the findings of this study show that improvements in air quality and reduction in concentrations of $PM_{2.5}$ pollutant in Mashhad can lead to a reduction in the rate of stroke mortality in this city.

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Footnotes

Authors' Contribution: Study concept and design: Sima Baridkazemi, acquisition of data: Khalilollah Moeinian, analysis and interpretation of data: Ali Taghipour, drafting of the manuscript: Ayat Rahmani. corresponding author: Hamidreza Nassehinia

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