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Association Between the Prevalence of Diabetes and $PM_{2.5}$: A Cross-Sectional, Ecological Study

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Abstract

Objectives: Many epidemiologic studies have drawn considerations to the adverse effects of air pollutants like particulate matter 2.5 (($PM_{2.5}$) on human health. This study aimed to analyze the association between the air concentration of $PM_{2.5}$ and the prevalence of diabetes in Mashhad.

Materials and Methods: This ecological study assessed the relationship between $PM_{2.5}$ level and diagnosed diabetes prevalence in the Mashhad metropolis by spatiotemporal analysis at the block level by data obtained from the Environmental Pollutants Monitoring Center and SINA electronic health records. The subgroup analysis was performed pursuant to age and gender. In addition, the kernel density estimation analysis and Pearson correlation were used to guesstimate the association between $PM_{2.5}$ and diabetes mellitus.

Results: A significant positive association was observed between $PM_{2.5}$ concentrations and the prevalence of diabetes. The results of the kernel density estimation indicated that the R and S zones with the highest prevalence rates of diabetes are among the zones with the highest $PM_{2.5}$ concentrations.

Conclusions: In general, the results showed that long-time exposure to $PM_{2.5}$ increases the prevalence of diabetes in Mashhad.

Keywords: Particulate matter, Diabetes, Iran

Introduction

Diabetes is one of the most public and chronic metabolic diseases which results from the lack of insulin or the presence of insulin resistance in peripheral tissues or both, leading to an increased concentration of glucose in the blood (1-3). It is estimated that diabetes rates rise from 108 million afflicted people in 1980 to 522 million by 2038 (4). The Middle East and North Africa have the highest prevalence of diabetes worldwide and Iran has the third rank (5).

Based on the reports, about 11.4% of people in Iran aged 25-70 years are afflicted with diabetes (6) and approximately 1% of the population over age 25 are yearly diagnosed with diabetes (7). A change in lifestyle, followed by physical inactivity and obesity, aging, genetic factors, and air pollution are the factors affecting the prevalence of diabetes (8, 9).

Air pollution is a serious problem worldwide and one of every eight deaths is attributed to air pollution (10). In addition, particulate matter (PM) is one of the most important air pollutants (11) and $PM_{2.5}$, can penetrate into the lower respiratory tract and even blood vessels because of its small sizes (12). It can be composed of various components such as organic and elemental carbon, metals, acidic chemicals, and the like. As a result, it can cause different effects on different parts of the human body (13).

Many epidemiological studies indicate that exposure to $PM_{2.5}$ can cause several diseases including diabetes (14-20). There is a significant positive correlation between long-term exposure to $PM_{2.5}$ and an increase in the risk of diabetes occurrence by 11% (21-26). PM affects humans through biological pathways including the increasing of arteriosclerosis, instigating changes in coagulation and blood cell response, and causing endothelial dysfunction and vasoconstriction (27,29). Further, particles affect the body through the biological routes of injection and spasm.

Considering the importance of diabetes and the effect of $PM_{2.5}$ on its prevalence, as well as the importance of Mashhad in terms of population, air pollution, and religious tourism, the current study aimed to evaluate the correlation between $PM_{2.5}$ concentration and prevalence of diabetes among the residents of Mashhad-Iran.

Materials and Methods

The metropolis of Mashhad is located in the province of Khorasan Razavi, Iran. Furthermore, the population of Mashhad is over 3.3 million people and it is the second most populous city in Iran. Moreover, this city is located in the geographical position of east longitude 59.35° to 59.74° and north latitude 36.14° to 36.48° and wind direction in

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the city is southeast to northwest. Additionally, Mashhad has an arid to semi-arid climate and its annual maximum, minimum, and average temperatures are 43°C, -23°C, and 15.3°C, respectively. The average annual rainfall is 239 mm as well (30,31).

Based upon the city map of Mashhad and using proximity tools (i.e., creating buffer and Thiessen polygons) in ArcMap, areas with a radius of up to 4 km were identified around each air quality monitoring station and thus the city of Mashhad was divided into 10 zones.

Diabetes prevalence data were collected from January 1, 2014, through January 1, 2016, via the SINA Electronic Health Record system (SinaEHR®), supervised by Mashhad University of Medical Sciences. The recorded data in this system include the health records of each individual, the reports of physicians and health care providers, prescribed prescriptions, laboratory results, procedures, diagnoses, and the other details of each patient's case. Similarly, it is an integrated health system that is managed by the cooperation and coordination of all stakeholders including managers, doctors, midwives, health care providers, and the like. In this study, patients with International Classification of Diseases (ICD-10) codes including E11 and E12 were regarded as diabetic cases.

Information about the total population, the total number of diabetics and their ages and genders, along with the latitude and longitude of each urban health center were collected individually. The total population living in Mashhad was considered as the population under study, who was diagnosed with diabetes in comprehensive health centers. In general, 13 951 patients were evaluated after eliminating all patients under 30. In addition, the location of each health center was identified by using geographic information systems in each of the ten zones, followed by calculating the prevalence of diabetes in males and females, along with middle-age and the elderly individuals for each zone. Based on the guidelines of the Ministry of Health and Medical Education of Iran, the target population of this study was divided into the middle-aged (30-59 years) and the elderly (≥60) groups.

The Environmental Pollutants Monitoring Center of Mashhad was established in the second half of 2013. The mission of this Center is to monitor environmental pollution in the urban environment and plan regulatory and administrative measures. Mashhad has 10 air quality monitoring stations and all of them are under the supervision of the above-mentioned center. The $PM_{2.5}$ data were collected as the daily average in μg/m^3 from all the 10 air quality monitoring stations during 2014-2016. The overall three-year average concentration of $PM_{2.5}$ for each air quality monitoring station (zone) was calculated and used for analysis.

In this study, SPSS software was used for data analysis. Furthermore, the Kolmogorov–Smirnov statistical method was utilized to determine the normality distribution of the studied variables. The Pearson correlation test was then used to specify the type and intensity of relationships between quantitative variables. Finally, the Kernel density estimation was performed using the ArcMap software to determine the probability density of the prevalence of diabetes based on $PM_{2.5}$ concentrations. All graphs were plotted using GraphPad Prism software.

Results

From the 21 951 patients with diabetes, people living in rural areas and those under 30 years of age were eliminated from this study and a total of 13 951 patients were examined in this study. The characteristics of the study population are presented in Table 1.

Table 2 provides the $PM_{2.5}$ concentrations of the 10 zones of Mashhad (2014-2016). The average $PM_{2.5}$ concentrations at all zones during the three years of the study period were higher than those of the Health Organization (WHO) guideline, namely, an annual $PM_{2.5}$ concentration of 10 μg/m^3 (32). Moreover, the Torogh, Resalat, and Sakhteman were the most polluted zones.

The results of the correlation analysis are shown in Table 3. The results of Pearson correlation analysis displayed a significant positive correlation between the total

Table 1. Descriptive Data for the Study Population, Mashhad, Iran, 2016

Zone Name	Total Population of Each Zone	The Population of Patients With Diabetes, No (%)				
		Total Number	Men	Women	Middle Aged (30-59 Years)	Elderly (≥60 Years)
Vila	25795 (5.3)	877 (3.4)	365 (41.6)	512 (58.4)	379 (43.2)	498 (56.8)
Sadaf	11060 (2.3)	261 (2.4)	112 (42.9)	149 (57.1)	104 (39.8)	157 (60.2)
Lashkar	60164 (12.5)	1468 (2.4)	490 (33.4)	978 (66.6)	895 (60.9)	573 (39.1)
Sajad	34619 (7.2)	817 (2.4)	242 (29.6)	575 (70.4)	474 (58.0)	343 (42.0)
Khayam	21800 (4.5)	630 (2.9)	185 (29.3)	445 (70.7)	340 (54.0)	290 (46.0)
Taghi Abad	32893 (6.8)	671 (2.0)	256 (38.2)	415 (61.8)	260 (38.7)	411 (61.3)
Nakhrisi	83150 (17.2)	2561 (3.1)	681 (26.6)	1880 (73.4)	1432 (55.9)	1129 (44.1)
Resalat (R)	152636 (31.6)	4518 (2.9)	1042 (23.1)	3476 (76.9)	2802 (62.1)	1716 (37.9)
Torogh	13075 (2.7)	455 (3.5)	130 (28.6)	325 (71.4)	279 (61.3)	176 (38.7)
Sakhteman (S)	47691 (9.9)	1693 (3.5)	377 (22.3)	1316 (77.7)	1013 (59.8)	680 (40.2)
Total	482833 (100)	13951 (2.9)	3880 (27.8)	10071 (72.2)	7978 (57.2)	5973 (42.8)

Table 2. Descriptive Data for Concentration of $PM_{2.5}$ by Zones, Mashhad, Iran, 2014-2016

Zone Name	Concentration of $PM_{2.5}$ (μg/m³)			
	Min	Max	Mean	SD
Vila	3.18	249.40	22.99	15.80
Sadaf	3.37	118.93	19.49	12.48
Lashkar	1.07	336.47	23.48	22.18
Sajad	1.97	213.75	26.93	26.87
Khayam	3.78	280.49	25.27	19.90
TaghiAbad	5.91	210.96	31.21	19.88
Nakhrisi	1.36	207.94	28.24	20.73
Resalat	5.57	880.75	39.06	65.99
Torogh	5.83	161.04	40.14	24.08
Sakhteman	4.20	178.77	33.21	20.26
Total	1.07	880.75	27.61	24.73

Note. PM: Particulate matter: SD: Standard deviation.

Table 3. Correlation Between the Concentration of PM2.5 and the Prevalence of Diabetes, Mashhad, Iran, 2016

Variable	Pearson Correlation Test	
	Correlation Coefficient	*P* Value
Total prevalence of diabetes	0.658	0.039
Prevalence of diabetes in middle-aged	0.710	0.021
Prevalence of diabetes in elderly	0.040	0.913
Prevalence of diabetes in men	0.290	0.417
Prevalence of diabetes in women	0.675	0.032

prevalence of diabetes, as well as the prevalence of diabetes in middle-aged and women with $PM_{2.5}$ concentration. These positive correlations are illustrated in Figures 1-3.

Figure 4 displays the probability map of the prevalence of diabetes density based on the Kernel density estimation. The results indicated that the distribution of diabetes prevalence in the urban zones of Resalat and Sakhteman in Mashhad is consistent with the data from the accumulation of pollutants in these areas. This assessment showed the greatest density of diabetes in the east and northeast regions of Mashhad, and the center of this density is in the Resalat area. Additionally, areas that have less diabetes density are more located in the suburbs and the lowest density is associated with western areas. In other parts of the city, the dispersion of the prevalence of diabetes covers the city similarly.

Discussion

No major study has so far focused on the relationship between diabetes and exposure to $PM_{2.5}$ in Iran and, to the best of our knowledge, the current study is the first of its kind in this field. According to the WHO (32), the annual average of the PM2.5 is s10 μg/m³. However, the mean concentration of PM2.5 in the ten studied zones of Mashhad was higher in this study). The Resalat zone, located in northeastern Mashhad and the Sakhteman zone had the highest average of $PM_{2.5}$ concentration, respectively

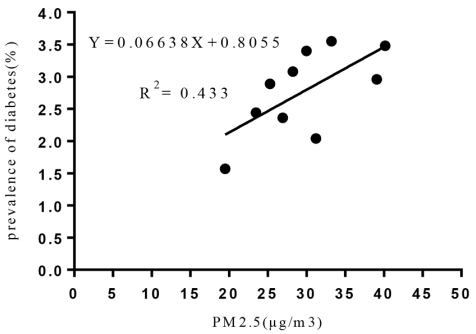

Figure 1. Linear Regression Between the Concentration of $PM_{2.5}$ and the Prevalence of Diabetes, Mashhad, Iran, 2016.

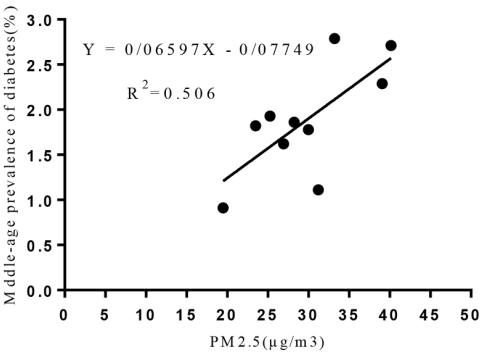

Figure 2. Linear Regressions Between the Concentration of $PM_{2.5}$ and the Middle-aged Prevalence of Diabetes, Mashhad, Iran, 2016.

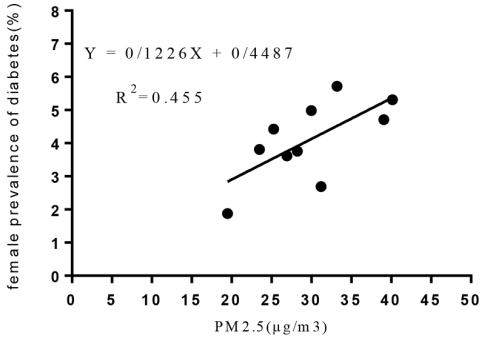

Figure 3. Linear Regressions Between the Concentration of $PM_{2.5}$ and the Female Prevalence of Diabetes, Mashhad, Iran, 2016

(Table 2). Several factors cause an accumulation of PM in these parts of the city, including the overcrowding of buildings, the accumulation of brick kilns, the high volume of traffic, and the direction of the prevailing winds in the area.

The results of this research presented a significant relationship (r=0.658, *P*=0.039) between exposure to $PM_{2.5}$ and the prevalence of diabetes, which is similar to the results of previous studies conducted on diabetic patients (21,25,33). Park et al observed that the growth of 10 μg/m³ $PM_{2.5}$ concentration raised the risk ratio to 1.40. They also reported a significant relationship between

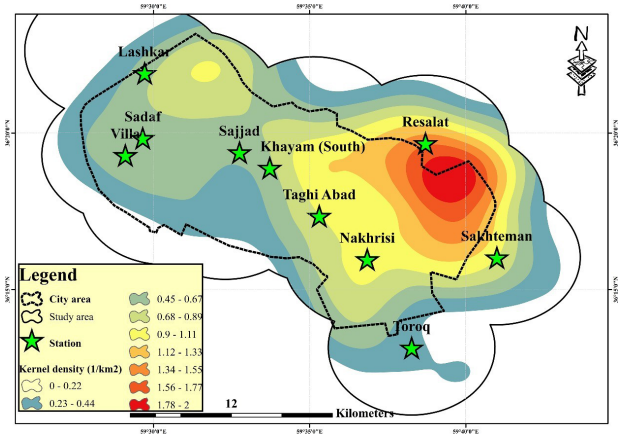

Figure 4. Density Map of the Prevalence of Diabetes, Mashhad, Iran, 2016

exposure to $PM_{2.5}$ and the prevalence of diabetes (22). In addition, Bowe et al (34) in a longitudinal cohort study tested the relationship of $PM_{2.5}$ and the risk of prevalent diabetes. They found that a 10 μg/m³ growth in $PM_{2.5}$ was related to the grown risk of diabetes (HR=1·15, 95% CI=1·08-1·22). Similarly, Oriol et al observed a significant positive association between $PM_{2.5}$ concentration and diabetes. In other words, the resulting odds ratio was 1.04 (95% CI 1.02-1.07) for each 10 μg/m³ growth in $PM_{2.5}$. Their study proposed a possible pattern of ozone as an independent operator related to the expansion of diabetes. Such association is of great growth for public health and merit subsequent studies (35).

Some studies suggested that PM increases diabetes through biological ways such as endothelial dysfunction, visceral adipose tissue, increased insulin resistance, and the impact on hemoglobin (36, 37). These observations confirm the relationship between $PM_{2.5}$ exposure and the increased prevalence of diabetes. The results of this research also present that there is a significant positive correlation (r=0.710, *P*=0.021) between $PM_{2.5}$ concentration and the prevalence of diabetes in the middle-aged group (30-59 years). In a study in the United States, Pearson et al showed that an increase of 10 μg/m³ of $PM_{2.5}$ concentration increases the diagnosis of diabetes by more than 10 000 people for a hypothetical population of about 1 000 000 people. Therefore, a strong correlation exists between the concentration of $PM_{2.5}$ and the prevalence of diabetes, especially in adults (12). Further, high levels of the outdoor activity of people aged 30-59 and a high probability of PM exposure are among the factors which help the prevalence of diabetes in this age range. The statistical analysis of this study showed a significant positive correlation (r=0.675, *P*=0.032) between exposure to $PM_{2.5}$ and the prevalence of diabetes in women. Likewise, Solimini et al found a significant positive ecological relationship between the age and gender of diabetic patients and the $PM_{2.5}$ concentration. More precisely, the hospitalizations of diabetic patients increased by 3.5% and 4% for men and women by an increase of one μg/m³ in $PM_{2.5}$ concentration (38). This could be on gender differences in susceptibility to air pollution. In the present study, the number of studied diabetic females was higher than that of the male due to more women referring to health centers thus further studies are needed in this area in the future.

Additionally, this study used kernel density estimation to show potential areas of the accumulation of diabetes prevalence, which is a less observed factor in studies conducted in this area. The identification and analysis of the density areas of diabetes prevalence provide opportunities for politicians and policymakers to do control measures more accurately and effectively. The findings of kernel density estimation revealed that the prevalence of diabetes in Mashhad has statistically a clustered and focused distribution. According to the results of this study, the Resalat and Sakhteman zones, which are the most important centers of diabetes prevalence, are also the areas with higher concentrations of $PM_{2.5}$. One of the limitations of this study is the lack of complete coverage of diabetes screening, especially in enormous areas of Mashhad. Therefore, caution should be exercised on the generalizability of the results of this study. Further, the results can be used to influence policymakers' decisions regarding air pollution in Mashhad. Interventions to diminish ambient air pollution may support reduce the diabetes burden as well (39).

Conclusions

The results of this research showed that exposure to $PM_{2.5}$ is related to the increased prevalence of diabetes in Mashhad. Furthermore, the exposure of middle-aged people and women to $PM_{2.5}$ and the prevalence of diabetes had a significant positive relationship. Further studies are needed to better understand the role of $PM_{2.5}$ in the prevalence of diabetes. Such studies can be about the chemical and elemental composition of the particles. Finally, the hypothesis of the relationship between $PM_{2.5}$ and the outbreak of diabetes may be designed as a prospective study.

Conflict of Interests

Authors have no conflict of interests.

Ethical Issues

The study protocol was approved by the Ethics Committee of Semnan University of Medical Sciences under the ethical code of IR.SEMUMS.REC.1396.97.

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