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The Relationship between Particulate Matter and Parameters of the Electrocardiogram and Blood Pressure in People with Type 2 Diabetes

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Abstract

Objective: This study aimed to investigate the relationship between particulate matter (PM) and electrocardiogram, blood pressure, and fasting blood sugar in people with type 2 diabetes mellitus.

Materials and Methods: In this study, we collected laboratory and clinical information from 270 patients with type 2 diabetes (T2DM) who were hospitalized at educational hospitals affiliated with Abadan University of Medical Sciences from March 21, 2023, to March 19, 2024. Information related to the concentrations of PM10 and PM2.5 was received from the Khuzestan Environmental Organization. To explore the relationship between PM2.5 and PM10 with clinical and laboratory factors, the Pearson Correlation Coefficient was utilized.

Results: The study showed that 53.3% of the patients were male, and the mean age was 60.32 (± 12.16) years. No significant relationship was observed between PM10 and PM2.5 with fasting blood sugar (*P*= 0.291), (*P*= 0.516), random blood sugar (*P*= 0.804), (*P*= 0.829), P-R interval (*P*= 0.289), (*P*= 0.163), S-T segment (*P*= 0.700), (*P*= 0.517), QRS voltage (*P*= 0.956), (*P*= 0.505), systolic blood pressure (*P* = 0.587), (*P*= 0.478) and diastolic blood pressure (*P*= 0.229), (*P*= 0.347). However, a significant relationship was observed between PM 10 and PM 2.5 with the Q-T interval (*P*= 0.042) and (*P*= 0.010).

Conclusion: Based on the results of the present study, no significant relationship was observed between PM with Clinical and laboratory parameters in people with type 2 diabetes, and only the relationship between PM and Q-T interval, which is one of the electrocardiographic parameters, was significant.

Keywords: Diabetes, Blood sugar, Particulate matter

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Introduction

Type 2 diabetes (T2DM) occurs when there is not enough insulin produced due to pancreatic beta cell dysfunction and when target organs become resistant to insulin. Rising obesity rates, sedentary lifestyles, and an aging population have led to its increased prevalence (1). T2DM mainly affects middle-aged and older adults due to prolonged high blood sugar from poor lifestyle and diet (2). Epidemiological studies show a relationship between exposure to Particulate Matter (PM) and an increased risk of T2DM; air pollution is a significant risk factor for diabetes (3).

The most important environmental risk factors are exposure to ambient air pollution and its health effects (4). Epidemiological studies have shown a positive association between exposure to air pollutants, especially for particles with a diameter of less than 2.5 μm (PM2.5), and the incidence of cardiovascular diseases. Long-term exposure to air pollution can accelerate the progression of atherosclerosis by promoting dyslipidemia, hypertension, and other metabolic disorders caused by systemic inflammation and oxidative stress (5).

Air pollution can increase the risk of diabetes through several mechanisms, including increased inflammation and oxidative stress. Given the association between diabetes and air pollution, preventive measures are needed to reduce the risk of this disease (6). Reducing air pollution may play a key role in reducing the global burden of disease caused by T2DM (3), especially PM2.5 particles, one of the most important health threats (7,8).

Numerous studies conducted in different countries worldwide show a relationship between air pollution and the risk of diabetes, the occurrence of diabetes, and its progression (9-14). Abadan, located in southwestern Iran, has been experiencing an increasing frequency and intensity of dust storms in recent years, primarily due to its proximity to the vast deserts of southern Iraq and Saudi Arabia, as well as local drought conditions. The city regularly experiences sand and dust storms. Given that Abadan city is exposed to annual dust and pollution from refineries, and considering the results of a previous study (15) indicating a high frequency of diabetic patients hospitalized in educational hospitals of Abadan University of Medical Sciences, and considering that no study in Abadan has investigated the relationship between environmental particulate matter and electrocardiogram parameters and blood pressure in diabetic patients, this study aimed to investigate the relationship between environmental PM and parameters related to electrocardiogram, blood pressure, and fasting blood sugar in individuals with T2DM.

Material and methods

This study was an analytical cross-sectional research. After obtaining ethical approval, we collected demographic information, laboratory results (fasting blood sugar (FBS), random blood sugar (BS), prothrombin time (PT), partial thromboplastin time (PTT), international normalized ratio (INR), Platelet (PLT)), ECG parameters (ST Segment, P-R interval, Q-T interval, and voltage of QRS), systolic blood pressure (SBP) and diastolic blood pressure (DBP)), from medical records of 270 patients with T2DM hospitalized from March 21, 2023, to March 19, 2024. This data was retrieved from the medical records department of the educational hospitals affiliated with Abadan University of Medical Sciences. Data on the concentration of environmental PM2.5 and PM10 was collected from the Khuzestan Environmental Organization from March 21, 2023, to March 19, 2024. The study investigated the relationship between environmental particulate matter and various health parameters, including cardiac electrocardiogram readings, blood pressure, blood sugar levels, coagulation factors, and medical history of the patients. In this study, PM concentrations were assessed according to the patients' hospitalization dates. The relationship between the annual mean PM

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concentrations and the patients' clinical and laboratory data was then analyzed.

The inclusion criteria for this study consisted of patients with T2DM mellitus who were diagnosed by an internal medicine specialist and an endocrinologist. These patients were hospitalized in the educational hospitals of Abadan University of Medical Sciences, (Ayatollah Taleghani Hospital, Shahid Beheshti Hospital, and Valiasr Hospital), from March 21, 2023, to March 19, 2024. Additionally, their clinical and laboratory information needed to be available in the patient records.

The exclusion criterion for the study included patients with T2DM mellitus who were hospitalized in the educational hospitals during this period but had incomplete or unavailable clinical and laboratory information.

Measurement of mass concentrations of PM

PM concentrations were measured using a Met One Beta Attenuation Meter (BAM-1020) at the air quality monitoring station (AQMS) on the rooftop of the Abadan Environmental Protection Agency, about 10 meters above ground level. Hourly sampling was conducted from March 21, 2023, to March 19, 2024. Meteorological data, including wind speed and direction, temperature, dew point, pressure, and humidity, were sourced from the Iran Meteorological Organization (www.irimo.ir) for analysis. The meteorological station was located at Abadan International Airport.

Measurement of electrocardiographic parameters

In this study, we reviewed standard 12-lead electrocardiograms (ECGs), which included six precordial leads (V1 to V6), three augmented limb leads (aVR, aVL, and aVF), and three limb leads (I, II, and III). The electrocardiographic parameters we measured were based on the findings from lead II.

Statistical analysis

All statistical analyses were conducted using SPSS software, version 16 (IBM Corp., Armonk, NY). Descriptive statistics, including frequencies, percentages, means, and standard deviations, summarized the demographic, clinical, and laboratory characteristics of participants. Pearson’s correlation coefficient was used to examine the relationship between PM2.5 and PM10 concentrations and continuous variables, including fasting blood sugar, random blood sugar, coagulation markers (PT, PTT, INR, PLT) and ECG parameters (P-R interval, Q-T interval and QRS voltage). One-way analysis of variance (ANOVA) assessed associations between particulate matter and the qualitative ST segment variable. Independent t-tests compared PM levels across groups defined by disease history (such as chronic kidney disease (CKD), hypertension, heart failure (HF), ischemic heart disease (IHD), hyperlipoproteinemia (HLP), dyslipidemia (DLP) and Cerebrovascular accident (CVA)) and disease outcomes (death or discharge). All statistical tests were two-tailed, and a *P*-value< 0.05 was considered statistically significant.

Sample size and power calculation

An a priori power analysis was conducted before data collection to determine the minimum required sample size. Assuming a small effect size (|r|= 0.25), a two-tailed significance level of α= 0.05, and a power (1-β) of 0.95, the estimated minimum sample size was approximately 197 participants, calculated using G*Power version 3.1. The final analytical sample included 241 eligible patients, exceeding the required sample size and ensuring adequate statistical power to detect significant associations.

Data cleaning and distributional assessment

All data were reviewed for completeness, plausibility, and consistency before analysis. Outliers and implausible values were identified through graphical inspection (boxplots,

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histograms, Q-Q plots) and numerical criteria, including the interquartile range (1.5×IQR) and standardized z-scores (|z|> 3). Implausible or incomplete records were corrected when possible or excluded from the final dataset. Of 270 reviewed records, 19 incomplete and 10 implausible cases were excluded, resulting in 241 valid observations.

The normality of continuous variables (e.g., fasting blood sugar, blood pressure, coagulation markers, and ECG parameters) was assessed using both graphical and statistical methods. The Shapiro-Wilk test was used for normality assessment, and for subsamples with n< 50, the Kolmogorov-Smirnov test was also applied. Given the sensitivity of the Kolmogorov–Smirnov test to large sample sizes, its results were interpreted alongside graphical evidence and distributional indices. Variables with skewness and kurtosis values within ±2 were considered approximately normal.

Ethical considerations

This study received approval from the Ethics Committee of Abadan University of Medical Sciences (Ethical Approval ID: IR.ABADAN UMS.REC.1402.103).

Results

Table 1 shows the frequency distribution and mean of demographic, laboratory, and clinical characteristics of patients with T2DM. According to the results, 46.7% of patients were female (126 patients) and 53.3% (144 patients) were male. The mean age of the patients was 60.32 (± 12.16) years. The examination of coagulation markers (PT, PTT, INR, PLT) showed that the mean PT was 14.24 (± 5.39) (higher than normal), the mean PTT was 36.95 (± 16.52), the mean INR was 1.22 (± 0.81) (higher than normal), and the mean PLT was 265.91 (± 114.87). Also, the mean systolic and diastolic blood pressure were 134.28 (± 28.92) and 80.15 (± 15.46), respectively, with the mean systolic blood pressure being higher than normal. The mean fasting blood sugar in the patients was also measured, and the mean was 189.8 (± 25.86), which is higher than the normal range.

The medical history of the patients revealed that 61.4% had a history of high blood pressure. The table results indicated that the mean P-R interval was 0.15 (± 0.03), the mean Q-T interval was 0.39 (± 0.02), and the mean QRS voltage was 0.83 (± 0.14), all of which fell within the normal range. Furthermore, the height of the S-T segment showed that 86.3% were normal, while 10.8% were elevated and 2.9% were depressed.

The relationship between PM and the variables under study in patients with T2DM

To investigate the relationship between environmental PM and the clinical and laboratory parameters in patients with T2DM, the Pearson correlation coefficient was used, and the results are presented in Tables 2 and 3.

The correlation coefficient between PM10 and Q-T interval was -0.131, and between Q-T interval and PM2.5 was -0.167. The significance level of the test was less than 0.05, indicating a significant relationship between PM10 and Q-T interval (*P*= 0.042) and Q-T interval and environmental PM2.5 (*P*= 0.010). The calculated correlation coefficients were negative, suggesting a significant indirect relationship between the two variables. Based on the correlation coefficient results between PM10 and PM2.5 and other studied variables, there is no statistically significant relationship (*P*> 0.05).

Discussion

This study investigated the relationship between environmental particulate matter and parameters related to electrocardiogram, blood pressure, fasting blood sugar and medical history in individuals with T2DM.
According to the correlation coefficient results, there is no statistically significant relationship between environmental particulate matter PM10 and PM2.5 with the studied factors except for the Q-T interval.

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Table 1. Frequency distribution and mean of demographic, laboratory, and clinical characteristics of patients with type 2 diabetes

Variable		Mean (± SD)	Frequency (%)
Age (year)	≤50 years	60.32 (± 12.16)	55 (22.8%)
	51-70 years		138 (57.3%)
	≥71 years		48 (19.9%)
Sex	Female		113 (46.9%)
	Male		128 (53.1%)
Progress	Death		48 (19.9%)
	Discharge		193 (80.1%)
PT (s)		14.24 (± 5.39)	
PTT (s)		36.95 (±16.52)	
INR		1.22 (± 0.81)	
PLT (10^3/µl)		265.91 (± 114.87)	
SBP (mm Hg)		134.28 (± 28.92	
DBP (mm Hg)		80.15 (± 15.46)	
FBS (mg/dL)		189.08 (± 86.25)	
BS (mg/dL)		281.09 (± 116.49)	
CKD	Negative		194 (80.5%)
	Positive		47 (19.5%)
Hypertension	Negative		93 (38.6%)
	Positive		148 (61.4%)
HF	Negative		191 (79.3%)
	Positive		50 (20.7%)
IHD	Negative		207 (85.9%)
	Positive		34 (14.1%0
DLP	Negative		230 (95.4%)
	Positive		11 (4.6%)
HLP	Negative		225 (93.4%)
	Positive		16 (6.6%)
CVA	Negative		205 (85.1%)
	Positive		36 (14.9%)
P-R Interval (s)		0.15 (± 0.03)	
Q-T Interval (s)		0.39 (± 0.20)	
ST Segment	Non		208 (86.3%)
	Elevated		26 (10.8%)
	Depretion		7 (2.9%)
Voltage of QRS (mV)	0.83 (± 0.14)		

SD: Standard Deviation PT: Prothrombin Time, PTT: Partial Thromboplastin Time, INR: International Normalized Ratio, PLT: Platelet, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, FBS: Fasting Blood Sugar, BS: Random Blood Sugar, CKD: Chronic Kidney Disease, HF: Heart Failure, IHD: Ischemic Heart Disease, DLP: Dyslipidemia, HLP: Hyperlipidemia, CVA: Cerebrovascular Accident

In a study by Shane et al. in 2020, it was observed that long-term exposure to high levels of PM10, SO_2 and NO_2 increases the risk of incident and mortality of T2DM in China (16). In a study by Elbarbary et al. in 2020, it was observed that an increase of 10 µg/m^3 in PM10 and PM2.5 was associated with an increase in the prevalence of T2DM, and a similar increase in PM10, PM2.5, PM1, and NO_2 was associated with an increase in HbA1c levels. In a large cohort of Chinese adults, air pollution increased the prevalence of T2DM and HbA1c levels (17). Oshidari et al. (2023) studied air pollution, diabetes, and blood pressure in adults from 11 Iranian metropolitan cities. In Isfahan, Ahvaz and Tehran, PM2.5 was associated with diabetes. In the cities studied, except Urmia, Yasuj and Yazd, PM2.5 was statistically associated with blood pressure. O_3 was associated with high blood pressure in Ahvaz, Tehran, and Shiraz. Poor air quality in large Iranian cities may cause diabetes and high blood pressure (18).

According to the results of Feizi et al. in Isfahan, exposure to air pollution was observed to increase the risk of T2DM and the incidence of prediabetes in the population. Exposure to air pollutants was also associated with an increasing trend in HbA1c, FPG, and OGTT levels (19).

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Table 2. Association between PM10 and PM 2.5 with clinical factors

Variable		PM10 Mean (± SD)	PM10 *P*-value	PM2.5 Mean (± SD)	PM2.5 *P*-value
Progress	Death	149.75 (± 112.26)	0.156α	69.94 (± 73.37)	0.119α
	Discharge	179.80 (± 135.06)		95.27 (± 105.88)	
CKD	Negative	173.91 (± 131.42)	0.982α	91.41 (± 103.76)	0.712α
	Positive	173.43 (± 131.57)		85.35 (± 87.36)	
Hypertension	Negative	167.94 (± 136.20)	0.583α	82.36 (± 93.43)	0.337α
	Positive	177.51 (± 128.24)		95.18 (± 104.91)	
HF	Negative	169.31 (± 131.49)	0.298α	88.11 (± 104.29)	0.523α
	Positive	191.03 (± 129.80)		98.34 (± 85.65)	
IHD	Negative	176.43 (± 132.69)	0.447α	91.69 (± 101.12)	0.580α
	Positive	157.91 (± 122.15)		81.36 (± 98.61)	
DLP	Negative	172.99 (± 130.51)	0.655α	89.41 (± 98.66)	0.566α
	Positive	191.15 (± 150.23)		107.28 (± 140.72)	
HLP	Negative	175.59 (± 131.76)	0.431α	90.76 (± 99.95)	0.759α
	Positive	148.81 (± 123.78)		82.75 (± 112.96)	
CVA	Negative	171.85 (± 133.73)	0.579α	87.47 (± 98.41)	0.311α
	Positive	185.02 (± 116.58)		105.95 (± 112.64)	
ST Segment	Non	176.29 (± 132.39)	0.700β	91.52 (± 100.90)	0.517β
	Elevated	153.21 (± 113.90)		72.68 (± 77.30)	
	Depretion	176.79 (±165.77)		117.17 (± 163.27)	

SD: Standard Deviation, α: *P*-value carried from Independent t-test, β: *P*-value carried from One Way-ANOVA test, PM: Particulate Matter, CKD: Chronic Kidney Disease, HF: Heart Failure, IHD: Ischemic Heart Disease, DLP: Dyslipidemia, HLP: Hyperlipidemia, CVA: Cerebrovascular Accident

Table 3. Association between PM10 and PM2.5 with laboratory and clinical parameters

Variable	PM10 r	PM10 *P*-value	PM2.5 r	PM2.5 *P*-value
PT (s)	-0.062	0.338	0.060	0.350
PTT (s)	-0.022	0.738	-0.016	0.802
INR	0.023	0.719	0.019	0.764
PLT (10^3/µl)	-0.046	0.478	-0.070	0.277
SBP (mm Hg)	0.035	0.587	0.046	0.478
DBP (mm Hg)	0.078	0.229	0.061	0.347
FBS (mg/dL)	-0.068	0.291	-0.042	0.516
BS (mg/dL)	0.016	0.804	-0.014	0.829
P-R Interval (s)	-0.069	0.289	-0.090	0.163
Q-T Interval (s)	-0.131	0.042*	-0.167	0.010*
Voltage of QRS (mV)	-0.004	0.956	-0.043	0.505

r: Pearson correlation coefficient, *: Statistically significant at $P< 0.05$, PT: Prothrombin Time, PTT: Partial Thromboplastin Time, INR: International Normalized Ratio, PLT: Platelet, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure; FBS: Fasting Blood Sugar, BS: Random Blood Sugar

In the study by Wu et al. (2022), air pollution was observed to be associated with different stages of T2DM progression, and significant associations between four air pollutants and the risk of cancer and cardiovascular disease mortality due to T2DM or diabetic complications were found. Exposure to ambient air pollution may contribute to the increased risk of T2DM onset and progression (14).

Determination of the association of PM with Q-T interval in patients with T2DM in our study showed a significant association between PM10 and Q-T interval and Q-T interval with PM2.5 particulate matter.

Q-T interval prolongation could be an integral effect of CO by increasing INaL, suppressing IK1, and subsequently prolonging APD (20). However, such an effect may also result from systemic inflammation induced by O_3, as the inflammatory cytokines contribute to electrical remodeling and prolong QTc (21).

The study of the relationship between PM and P-R interval, S-T height, QRS voltage, and systolic and diastolic blood pressure also showed in the present study that there was no statistically significant relationship between environmental particulate matter PM10 and PM2.5 and the variables under study. In other

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words, environmental particulate matter did not affect P-R interval, S-T height, QRS voltage, or systolic and diastolic blood pressure.

The difference in the results of different studies can be related to various reasons, one of which is the statistical population under study, which should be conducted at a wider level, or the PM air data from the provincial meteorology should be more accurate and recorded for all days of the year, which would increase the accuracy and results of the studies. More studies in this field with a larger sample size and separating polluted and non-polluted days are needed.

This study had several limitations. This study aimed to evaluate the short-term relationship between particulate matter (PM10 and PM2.5) and various health parameters, including electrocardiogram parameters, blood pressure, and fasting blood sugar levels, in patients with diabetes. It is recommended that longitudinal or cohort studies be conducted to investigate the long-term effects of particulate matter on these health factors.

It was conducted at educational hospitals affiliated with Abadan University of Medical Sciences in southwestern Iran and included a small sample size within a limited geographical area. Consequently, the findings cannot be confidently generalized to other populations. Additionally, the data were not categorized by disease type or severity due to the small number of subjects involved. Therefore, it is recommended that future studies utilize a larger sample size, include more diverse populations, and examine both disease type and the severity of diabetes.

Conclusion

The results of this study indicate a significant association between PM and the Q-T interval in patients with T2DM. Therefore, more comprehensive and in-depth research is needed to better understand the effects of air pollutants on cardiovascular diagnostic markers in individuals with diabetes, ideally involving a larger sample size.

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Conflict of Interest

The authors confirm that there are no conflicts of interest.

Authors' contributions

E.R: Conceptualization, Project administration, Methodology, Investigation, collecting the data, Writing-Review & Editing, A.S: collecting the data. Methodology, Investigation, Writing- Review & Editing, N.K: Formal Analysis, Investigation, Writing-Review & Editing, M.B: Methodology, Investigation, Review & Editing, Gh.G: Methodology, Investigation, collecting the data, Review & Editing.

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