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Short-term effects of exposure to $PM_{2.5}$, PM_{10}, NO_2, CO, SO_2, O_3 on lung function test indices among students of Tehran city, Iran

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ABSTRACT

Introduction: The adverse health effects of air pollution have been observed in many epidemiological studies. The aim of this research was to study the effects of air pollution on pulmonary functions in schoolchildren in Tehran city.
Materials and methods: Total number of 167 schoolchildren were selected to participate in this study. Data were analyzed using analysis of variance (ANOVA) and generalized estimating equation (GEE) to determine the relationship of air pollution and lung function tests.
Results: The result of this study showed that there are statistically significant differences in value of air pollution between areas. The results present that concentration of O_3, PM_{10}, NO_2 has a negative association with lung function tests but concentration of CO, $PM_{2.5}$, and SO_2 had no association with decreased lung function tests. Time variable of air pollution was not statistically significant effect on lung function test.
Conclusion: In this study, we conclude that air pollution in Tehran city can be decreased lung function test indexes that may be affected by short-time exposure to air pollutant.

Introduction

Air pollutants produced by industrial activities and vehicles such as O_3, SO_2, NO_2, CO, $PM_{2.5}$, PM_{10} have adverse effects on the respiratory system [1, 2]. The adverse effects are more pronounced in children because they are more sensitive when exposed to contaminated air. Children have a lower diameter of airways, and they generally breathe more air per kg of body weight than adults, so exposure to more air pollutants. Increased concentrations of air pollutants cause more inflammation in the respiratory system [3]. Children spend more time and more activity outdoor; hence more susceptible to exposure to air pollutants [4].

Numerous studies postulated that air pollution had adverse effects on the respiratory system that are more serious in large and industrial cities [5]. Spirometry has been used in several studies to show the effects of air pollution on the respiratory system. Indicators measured by spirometry include FVC, FEV1/ FVC, FEV1, MMEF2575,

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FEV1/ FEV6. Most studies examining the short-term effects of air pollution on spirometry indices performed a single spirometry test and have not evaluated changes in spirometry indices during a period time which are essential in determining the exact effect of air pollutants on the respiratory system [6].

Therefore, we decided to study the effect of air pollutants on the respiratory system of children by performing two spirometry tests for each child and to evaluate the changes in spirometry indices. Our study was performed in Tehran, the capital city of Iran, which is one of the most polluted cities in this country.

Materials and methods

Study design

This was a prospective cohort study conducted between September, 2018 and May, 2019.

Inclusion criteria

Students without a history of respiratory disease and recent illness and who were taking no medications were included in this study.

Participants

In this study, 167 male and female fifth-grade elementary school students, aged between 10 to 12 years old, participated. The students were randomly selected from 10 schools in five municipal districts of the city, which were less than 500 m from air quality monitoring stations. The Height and weight of all of the students were measured. A questionnaire, including questions on drug history, asthma, allergy, eczema, and parent smoking, was given to each student's parents. The study protocol was approved by the Ethics Committee, The Iran University of Medical Sciences.

Data on the levels of air pollutants

The levels of air pollutants such as O_3, SO_2, NO_2, CO, $PM_{2.5}$, PM_{10} were obtained from the Tehran Air pollution Assessment website [7]. In both first and second episodes of spirometry, the levels of air pollutants were recorded on the day of performing spirometry (Lag0) and five consecutive days before that (Lag01–Lag05). The changes in the levels of air pollutants between the first and second episodes of performing spirometry were calculated. Less than 5% of data on the levels of air pollutants was missed due to technical errors in air monitoring sensors.

Lung function test

Spirometry was performed with a portable spirometer (Spiro lab mobile version, China). The spirometer was calibrated using a 3 L syringe each time before spirometry. Spirometry was performed by expert technicians. In the beginning, the spirometry method was fully explained to the students. Three to five spirometry maneuvers were acquired from each student, and the best maneuver was selected based on American Thoracic Society/European Respiratory Society (ERS) criteria.

Statistical analysis

The mean daily concentration of air pollutants on the day of the first and second time of spirometry in 5 districts (Lag0) and 1–5 days before the first and second time of that (lag1-5) were measured and compared between five studied sites. Percentage of changes of air pollutant concentration and spirometry indices were calculated between first and second times. In this study, multiple regression using Generalized Estimating Equation (GEE) statistical models were used to determine the correlation between changes of lung function indices (FVC, FEV1, FEV1/FVC, FEV1/FEV6 and FEF25-75) and changes in air pollutants (0 days to 5 days before spirometry). Statistical analyses (GEE, ANOVA) were performed using SPSS (version 22), and statistical significance for $P<0.05$ were considered.

Table 1. Demographic profile of the study participants

Variables	Region 1	Region 2	Region 3	Region 4	Region 5	Total	P-value
No	37	37	31	37	25	167	
Male	51.30%	48.60%	35.40%	37.80%	0%	37.10%	
Female	48.60%	51.30%	64.50%	62.10%	100%	62.90%	
Height (cm)	152.6±7.3	153.4±8.5	150.2±10.4	151.3±8.8	153.2±7.0	152.0±8.4	p=0.49
Weight (kg)	49.2±13.4	49.5±10.5	48.0±11.3	47.4±13.6	49.6±9.5	48.7±11.8	p=0.92
BMI	21.0±5.0	20.9±3.5	21.5±5.3	20.4±4.0	21.0±2.6	20.9±4.2	p=0.90

Table 2. The results of the mean daily concentrations of air pollutants

	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
SO_2 (ppb)	Lag0	Lag1	Lag2	Lag3	Lag4	Lag5
First time	3.5±1.4	3.1±1.4	3.5±1.8	3.7±2.4	4.1±2.3	4.3±2.1
Second time	4.3±1.2	4.3±1.0	4.7±1.8	3.5±1.5	3.9±1.1	3.9±1.0
Percentage of changes	37.6±51.3	60.4±62.1	50.3±55.4	16.5±51.4	12.9±59.5	37.6±51.3
NO_2 (ppb)						
First time	45.0±5.0	42.9±5.5	43.7±9.2	45.5±15.2	43.9±10.4	47.2±14.6
Second time	49.0±11.0	48.8±6.7	47.7±10.2	41.7±10.8	44.8±7.6	49.9±9.0
Percentage of changes	10.2±20.3	15.4±18.9	13.2±25.1	-1.5±28.3	2.3±26.5	5.0±43.4
CO (ppm)						
First time	1.4±0.3	1.3±0.3	1.3±0.5	1.5±0.6	1.3±0.4	1.7±0.5
Second time	1.7±0.9	1.7±0.5	1.4±0.4	1.3±0.4	1.4±0.7	1.5±0.9
Percentage of changes	23.7±69.4	33.8±47.2	17.3±37.5	-6.0±32.0	1.3±27.6	-0.2±60.2
O_3 (ppb)						
First time	16.5±5.5	22.6±6.6	17.1±8.5	20.9±6.7	18.3±7.4	17.0±6.3
Second time	16.3±8.5	15.0±7.5	18.3±8.9	19.0±10.7	17.9±8.9	16.7±7.0
Percentage of changes	-9.3±43.4	-32±31.5	-10.8±43.5	-9.1±50.7	-3.9±39.7	11.3±47.7
$PM_{2.5}$ (μg/m³)						
First time	18.1±6.9	125.5±5.1	23.1±12.5	25.7±14.5	24.9±11.6	25.7±13.8

Results and discussion

In total, 167 male and female fifth-grade elementary school students, aged between 10 to 12 years old, were included in this study. The students were randomly selected from 10 schools in five districts of the city. The students' characteristics are shown in Table 1.

The average and standard deviation (SD) of height, weight, age, and BMI were not different between students of five municipal districts. The results of the mean daily concentrations of air pollutants are displayed in Table 2.

The spirometry indices and percentage of changes are presented in Table 3.

The results using GEE (Generalized Estimating Equation) are shown in Table 4.

Table 3.The spirometry indices and percentage of changes

	Mean (SD)	Mean (SD)	Mean (SD)
	First time	Second time	percentage of changes
FEV1 (L)	2.1 (0.85,3.12)	2.0 (0.88,3.02)	-0.5 (-61.3,95.2)
FVC (L)	2.3 (1.21,3.42)	2.2 (1.1-3.2)	-2.0 (-40.82,57.95)
FEV1/FVC (%)	90.5 (40.6,100.0)	90.5 (40.6,100.0)	1.6 (-54.3,89.8)
FEV1/FEV6 (%)	90.6 (40.6,100.0)	91.2 (41.3,100.0)	1.4 (-54.3,89.8)
FEF25-75 (L)	2.7 (0.5,4.99)	2.6 (0.6,5.3)	5.1 (-71.5,160.0)

Table 4. The results obtained by Generalized Estimating Equation (GEE)

	B	P-value	B	P-value	B	P-value	B	P-value	B	P-value
Time	0.425	0.177	0.178	0.52	0.253	0.189	0.243	0.199	0.784	0.17
O_3	-0.058	0.006	-0.04	0.013	-0.018	0.145	-0.017	0.178	-0.085	0.023
CO	0.003	0.856	-0.005	0.78	0.009	0.337	0.009	0.333	0.019	0.516
NO_2	-0.106	0.007	-0.087	0.005	-0.018	0.531	-0.014	0.614	-0.134	0.167
SO_2	0.028	0.127	0.011	0.462	0.017	0.139	0.017	0.135	0.025	0.46
PM_{10}	0.037	0.008	0.039	0.007	-0.003	0.679	-0.004	0.611	0.025	0.344
$PM_{2.5}$	-0.009	0.616	-0.021	0.222	0.013	0.117	0.012	0.142	0.026	0.371

Table 4 shows that a one ppb increase in O_3 was associated with a change of -0.058 L in FEV1 (95% CI: - 0.099–0.017 L) and -0.04 in FVC (95% CI: -0.072– -0.008 L) and -0.085 L in FEF25-75 (95% CI: -0.158– -0.012 L), after adjustment for gender and height. Our study demonstrates that 1 a ppb increase inNO_2 was associated with a change of -0.106 L in FEV1 (95% CI: -0.183– -0.029 L) and -0.087 L in FVC (95%CI: -0.149– -0.026L), after adjustment for gender and height. This study also displayed that 1 μg/m³ increase of PM_{10} was associated with a change of 0.037 Lit in FEV1 (95% CI: 0.010– 0.065 L) and 0.039 Lin FVC (95% CI: 0.011–0.068 L), after adjustment for gender and height. Other air pollutants had no significant effect on spirometry indices.

The present study included 167 male and female fifth-grade elementary school students, aged between 10 to 12 years. This age range was chosen because of more inadequate cooperation in younger children. This study was conducted on healthy elementary school students without any previous illness.

Air pollutants produced by industrial activities and vehicles such as O_3, SO_2, NO_2, CO, $PM_{2.5}$, PM_{10} have adverse effects on the respiratory system [2]. Our study assessed the effects of the daily average concentration of air pollutants on spirometry indices. Previous studies have demonstrated that elevated air pollutants were associated with more decrease in lung function in children than adults [4]. Several previous studies have examined the associations between spirometry indices and air pollutants [5, 8-12] but those studies did not consider changes in spirometry indices in individuals. In those studies, the concentration of air pollutants in the days before spirometry was measured.

Most longitudinal studies investigated the effects of air pollution on lung function tests of adolescents aged 12 to 16 years and reported that FVC, had a significant adverse association with short-term exposure to O_3 and PM_{10} measured on the day of spirometry testing [12]. FVC values also were reversely associated with means of CO, O_3, NO_2, PM_{10} and SO_2 exposed 1 day earlier. An increase of 1ppm CO was associated with the reduction in FVC for 69.8 mL (95% CI: -115, -24.4 mL) or in FEV1 for 73.7 mL (95% CI: -118, -29.7 mL). Their study also showed that an increase in SO_2 for 1 ppb was associated with the reductions in FVC and FEV1 for 12.9 mL (95% CI: -20.7, -5.09 mL) and 11.7 mL (95% CI: -19.3, -4.16 mL), respectively. This study similar to other previous studies did not evaluate changes in spirometry indices of each individual during a period, time.

Another difference between the change study and ours was that they found the time lag between the air pollutant measurement and spirometry day had a significant effect on spirometry indices. Nevertheless in our study, there was no significant relationship between the time lag and air pollutant levels. Another study performed in Ahvaz, a major city in the southwest of Iran, demonstrated a significant correlation between the increase of mean concentration of NO_2 in 1 to 4 days before sampling day and decreased FVC and FEV1 [13]. In this regard, by increasing the mean NO_2 concentration to 6.5 ppb, the values of FVC and FEV1 decreased by 12 and 19 mL; and by increasing the mean concentration of $PM_{2.5}$ to 13 μg/m³ on the same day of sampling (lag 0), the values of FVC and FEV1 decreased by 131 and 110 ml. However, similar to most previous studies, they did not evaluate spirometry changes within a period, time.

In our study, ozone harmed FEV1, FVC and FEF25-75, with the most significant effect on FEF25-75. It should be noted that although these effects are statistically significant, they are clinically insignificant and they did not cause symptoms in the students.

In normal subjects, the cut-off for clinically significant week-to-week changes of FEV1 and FVC were more than 12% and 11%, respectively. In our study, 61.6% of the subjects had FEV1 change less than 12% and 63.4% had FVC change less than 11%. In fact, in most subjects, although the percentage of spirometry changes was statistically significant, the indices remained within the normal range.

Conclusion

Our research suggests that air pollution in Tehran city can lead to decreased lung function test indices which may be affected by short-time exposure to air pollutants. Traffic-related air pollutants show acute and sub-acute adverse effects on the respiratory system in school children. Accordingly, our research suggests air pollution changes are associated with changes in lung function in a healthy subject. These findings can help improve understanding adverse effects of air pollution on the respiratory system, and may also implicate more targeted and effective pollution regulations to reduce traffic emission pollutants.

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Competing interests

The authors have no conflict of interest.

Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by GholamrezaAlizadeh Attar. The first draft of the manuscript was written by GholamrezaAlizadeh Attar and all authors revisedtheprevious versions of the manuscript. All authors read and approved the final manuscript.

Ethical considerations

Ethical approval for the study was obtained by the Ethics Committee of Iran University of Medical Sciences (approval code IR.IUMS.FMD.REC.1397.073). All participants were provided written informed consent before the study and had the right to withdraw from the study at any stage.

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