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Air Pollution Effects on Peak Expiratory Flow Rate in Children

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ABSTRACT

Airway mucus hypersecretion Health effects caused by air pollutants may range from subtle biochemical or physiological signs, such as mildly reduced lung function, to difficult breathing, wheezing, coughing and exacerbation of existing respiratory conditions such as asthma. The aim of this study was measuring the adverse health effects of air pollution on lung function of primary school students.

The lung function of students was measured daily for seven weeks in two elementary schools in District 12 of Tehran, after obtaining permission from the two principals and signed parents' consent forms. Twenty four hourly air pollution levels were used as potential predictors of lung function. The principal analysis conducted was a logistic regression on a subset of the data using a case-crossover design.

The outcomes data consisted of the results of lung function tests for 356 female and 206 male students over the six-week period. Using the difference between mean (87) and maximum (125) concentration of moving average of NO in this period to judge the size of the effect, such an increase in NO is predicted to lead to an increase in the probability of poor lung function (OR=20) based on population-based predicted value.

This study has shown strong and consistent associations between children's poor lung function and outdoor air pollutants in District 12 of Tehran for some pollutants. The strong association found in this study was an increase in seven-day moving average of NO using both definitions.

Key words: Air Pollution; Asthma; Children; Poor Lung Function; Prevalence

INTRODUCTION

Epidemiological studies have demonstrated a clear association between air pollution as it occurs in various places around the world and lung function.[1-9] Acute effects of urban air pollution on respiratory health of children were reported in many researches.[10]

Although a fairly large number of studies have explored the respiratory impacts of air pollution, because of its unique location and the children as

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susceptible population to air pollution we studied the association between air pollutants and respiratory symptoms of primary school children in Tehran for the first time. The question is whether air pollution, as it occurs in Tehran, will show similar association with respiratory health of primary school children.

This article addresses the association between air pollution levels and the poor lung function.

MATERIALS AND METHODS

Data Collection

Lung function data were collected on students in two schools. Over seven weeks, daily measurements of peak expiratory flow rate (PEFR) were obtained using a mini-Wright flow meter. The recorded lung function (PEFR) for the first week was removed from the database, as this was treated as a learning period.

The recorded measurements for the remaining six-week period were analysed. During the period, six measurements per week were taken on each child, there being no school on Fridays.

Data Analysis

Case-crossover analysis of the data used worst lung function definitions.[11] The presence of poor lung function is more complex than often presented. A Case date would be any date which lung function measured less than 50% the predicted value or the personal best blow. Thus the case definition for case-crossover analysis uses two alternative definitions of poor lung function for the analyses.

Two definitions of poor lung function case were used. Using a definition of poor lung function based on PEFR less than 50% of predicted value, the case date for each student identified as having poor lung function was the date of worst lung function.

The second definition of poor lung function used the best PEFR that each student produced during the six-week data collection period was identified. Subjects were deemed eligible to be a case if any observed PEFR was below 50% of the student's best PEFR (best blow).

Each such student was identified as a case on the day of his or her worst lung function. The method of defining a case and case date were otherwise the same as for the first definition of case.

The case date is defined as the date of worst lung function for each person according to either definition one or two. The control dates are two weeks before and after each case date. Therefore, by definition, a student is his or her own control on a day of better lung function. However, that day's lung function may measure (by either definition).

Statistical Model

Conditional logistic regression was used to analyse case-crossover data, with the response variable taking the value 1 for a case and 0 for a control. Variables used as putative predictors in the regression model were daily average of air pollution based on the teaching shift, seven-day moving averages of air pollutants, daily temperature and squared temperature (allowing the model to incorporate a non-linear temperature effect. The daily averages based on teaching shift are calculated for a 24 hour window which differs between teaching shifts, since the morning shift runs from 09:00 to 13:00 and the afternoon shift runs from 13:00 to 17:00 (times to be verified).

RESULTS

The air pollution and lung function data are summarized in Table 1-6 and Figure 1-8. The lung function data consisted of the results of 4,088 lung function tests on 356 girls and 3,112 tests on 206 boys. The pollution data are a temporal subset of the values described.[12]

Although there were significant data integrity problems for air pollution over the study period of over two years, the case-crossover analysis only needed data on case and control dates (and, for the calculation of one week moving averages, the immediately preceding seven days.

As indicated in Table 1 and Table 2, the air pollution data for Fatemi look insufficient to analyse. However, since case-crossover analysis just needs the case dates, air pollution data for Fatemi were used in this study.

In addition, there were no SO_2 data for either station during the seven week period of lung function data collection, so this was necessarily removed from the list of potential predictors.

Lung Function Based on Predicted Value

The descriptive data of worst lung function based on the predicted value (case definition one) are summarized in Table 3. Pollutants exposures used were the average of the current and seven-day moving average based on the teaching shift.

Table 1. Summary statistics for air polluion data

Variables	N (Days)	N Miss (Days)	Minimum ($\mu g/m^3$)	Median ($\mu g/m^3$)	Mean ($\mu g/m^3$)	Maximum ($\mu g/m^3$)	Std Dev
Fatemi							
SO_2	-	43	-	-	-	-	-
PM_{10}	24	19	35	86	90	165	39.3
NO	24	19	58	92	97	160	24.6
NO_2	24	19	91	133	142	224	39.0
NO_X	24	19	86	132	137	229	37.6
O_3	10	33	4	8	7	14	3.2
CO	24	19	5703	9219	10167	16828	2874.9
Bazaar							
SO_2	-	43	-	-	-	-	-
PM_{10}	42	1	30	84	324	5000	1046.4
NO	42	1	14	68	76	207	36.2
NO_2	32	11	24	30	33	48	7.0
NO_X	42	1	10	66	73	178	29.9
O_3	27	16	28	31	37	117	22.4
CO	42	1	3078	10589	9466	20172	4109.2

Table 2. Summary of distribution of coefficients for significant air pollutants at Fatemi station

	MA PM10	MA NO	MA CO
100% (Max)	4	9.2	78.8
75% (Q3)	0.8	1	4.2
50% (Median)	0.3	0.2	-6.9
25% (Q1)	-0.2	-0.6	-18.6
0% (Min)	-4.7	-8.6	-80.9

Estimates of the increase in prevalence are shown using the hazard ratio. As indicated in Table 3, there were 70 cases of worst lung function using predicted value and 140 control observations which is 2 controls per case. The average lung function was 101 L/min. A matched conditional logistic regression was carried out to investigate the relationship between an outcome and a set of prognostic factors in matched case-control studies. This analysis used the PHREG procedure in SAS, with a conditional logistic model and a stratum for each matched set.

The results of case-crossover analysis are presented in Table 4. Stepwise backward elimination was used to choose the final model in which the seven-day moving average of PM_{10} and NO from Fatemi were the pollution variables significantly associated with poor lung function (see Table 4).

In addition, using the difference between mean (81) and maximum (133) concentration of moving average of PM_{10} in this period to judge the size of the effect, such an increase in PM_{10} is predicted to lead to a decrease of poor lung function rate of 0.1. Using the difference between mean (87) and maximum (121) concentration of moving average of NO in this period to judge the size of the effect, such an increase in NO is predicted to lead to an increase in the probability of poor lung function (OR = 19).

Lung Function Based on Best Blow

The descriptive data of worst lung function based on best blow (case definition two) are presented in Table 5. As indicated in Table 5, there were 166 cases of worst lung function using personal best blow and 332 control observations (two weeks before and after case dates). The average lung function was 125 L/min.

Conditional logistic regression using the PHREG procedure in SAS was performed, and used a conditional logistic model with a stratum for each matched set.

Table 3. Summary statistics for lung function data based on case definition 1 and corresponding air pollution data over six weeks

Variable	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Lung function	210	0	60	100	101	140	20.8
Height	210	0	113	129	131	151	9.7
Age	210	0	6	8	8	11	1.3
Fatemi							
SO_2	0	210	-	-	-	-	-
PM_{10}	102	108	36	72	76	146	49.1
NO	102	108	66	90	91	160	26.6
NO_2	102	108	91	125	130	224	41.2
NO_X	102	108	86	116	126	229	39.9
O_3	54	156	4	6	7	14	3.3
CO	102	108	5	7	8	13	2.3
MA PM_{10}comb	158	52	39	81	81	133	18.2
MA NO comb	158	52	23	88	87	121	13.8
Bazaar							
SO_2	0	210	-	-	-	-	-
PM_{10}	198	12	30	78	81	157	30.3
NO	204	6	14	64	69	161	28.0
NO_2	168	42	25	30	33	48	7.3
NO_X	204	6	10	63	67	137	23.4
O_3	138	72	28	31	38	117	24.1
CO	204	6	2	9	8	16	3.3

-Not available

The results of case crossover analysis are presented in Table 6. All risk factors such as daily temperature, squared temperature, school, teaching shift, their interactions, seven-day moving average of daily air pollution PM_{10} from Fatemi, NO, NO_2, O_3 and CO comb at both stations (see Table 6) were included in the initial model. Stepwise backward elimination was used to choose the final model in which the seven-day moving average of PM_{10}, NO and CO at Fatemi station were the pollution variables significantly associated with poor lung function. From Fatemi station, using the difference between mean (83) and maximum (140) concentration of moving average of PM_{10} in this period to judge the size of the effect, such an increase in PM_{10} is predicted to lead to a decrease in the probability of airway obstruction (OR = 0.1).

Table 4. Conditional logistic regression for lung function based on predicted value

Variable	Parameter Estimate	Standard Error	Chi Square	Pr>Chi-Square	Hazard ratio	(95%CI) Lower	upper
Daily Temperature (T)	0.34	0.19	3.33	0.07	1.4	1.0	2.0
T^2	-0.02	0.01	2.13	0.14	1.0	1.0	1.0
Shift	0.24	0.38	0.41	0.52	1.3	0.6	2.7
$MAPM_{10}$ comb(F)*	-0.05	0.02	4.94	0.03	0.9	0.9	1.0
MA NO comb(F)*	0.08	0.03	5.94	0.01	1.1	1.0	1.2

* Statistically significant p = 0.05

Table 5. Descriptive data of lung function based on definition 2 and air pollution

Variable Lung function (BB)	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Fatemi	498	0	60	120	125	220	31.0
SO_2	0	498	-	-	-	-	-
PM_{10}	260	238	24	89	91	165	39.1
NO	260	238	43	92	94	160	25.3
NO_2	260	238	74	133	140	224	38.5
NO_X	260	238	62	132	134	229	37.4
O_3	156	342	4	8	8	17	3.7
CO	260	238	4	8	8	13	2.2
MA PM_{10} comb	375	123	19	84	83	140	20.6
MA NO comb	375	123	17	87	88	125	16.5
MACOcomb(ppm)	375	123	2	8	8	11	1.4
Bazaar							
SO_2	0	48	-	-	-	-	-
PM_{10}	443	55	30	87	91	184	35.2
NO	449	49	6	67	75	207	31.8
NO_2	361	137	25	30	33	48	6.6
NO_X	449	49	5	66	72	178	26.2
O_3	296	202	28	31	37	145	23.0
CO	469	29	2	9	8	16	3.2

- Not available

Using the difference between mean (88) and maximum (125) concentration of moving average of NO in this period to judge the size of the effect, such an increase in NO is predicted to lead to an increase in the probability of airway obstruction (OR = 80). Using the difference between mean 8 and maximum 11 concentration of moving average of CO in this period to judge the size of the effect, such an increase in CO is predicted to lead to a decrease in the probability of airway obstruction (OR = 0.1).

Table 6. Conditional logistic regression for lung function at Fatemi

Variable	Parameter Estimate	Standard Error	Chi-Square	Pr>Chi-Square	Hazard ratio	(95%CI) Lower	upper
Daily Temperature (T)*	0.41	0.13	9.48	0.0021	1.5	1.2	2.0
T^{2*}	-0.02	0.01	6.22	0.0126	1.0	1.0	1.0
Shift	0.20	0.28	0.54	0.4606	1.2	0.7	2.1
Gender	-0.29	0.41	0.50	0.478	0.8	0.3	1.7
Shift × Gender	0.15	0.62	0.05	0.8156	1.2	0.3	3.9
MA PM_{10} comb(F)*	-0.04	0.01	6.99	0.0082	1.0	0.9	1.0
MA NO comb(F)*	0.12	0.04	11.09	0.0009	1.1	1.1	1.2
MA CO comb(ppm)(F)*	-1.02	0.36	7.89	0.005	0.4	0.2	0.7

*Statistically significant p = 0.05 MA: seven-day moving average

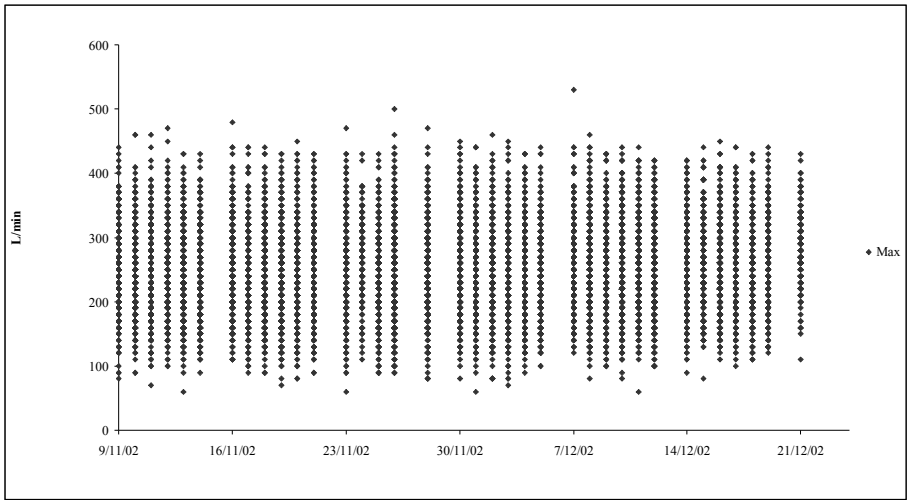

Figure 1. Daily lung function of all students during a six-week period

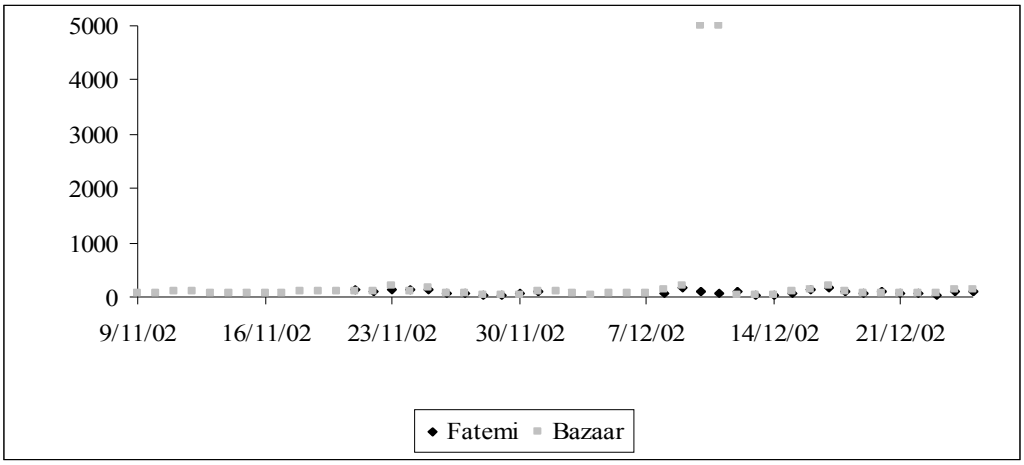

Figure 2. Daily PM_{10} levels over six-week, units in $\mu g/m^3$ for the morning teaching shift

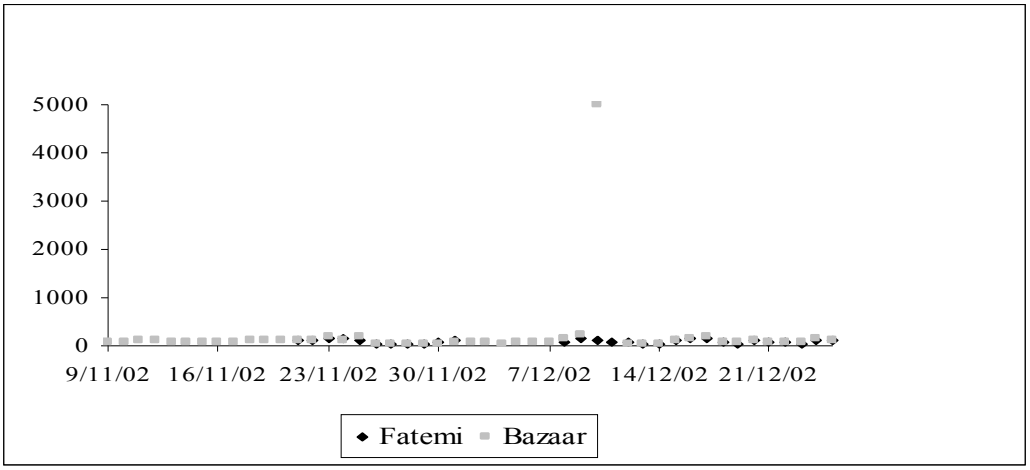

Figure 3. Daily PM_{10} levels over six-week, units in $\mu g/m^3$ for the afternoon teaching shift

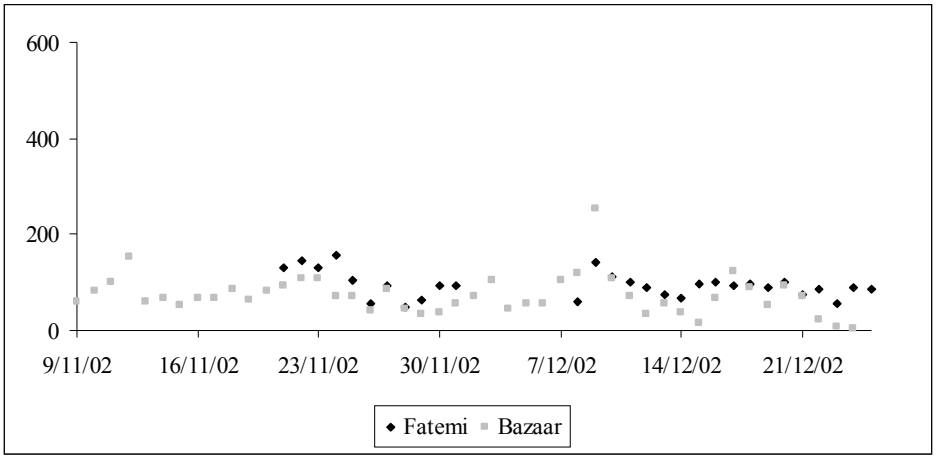

Figure 4. Daily NO levels over six-week, units in μg/m^3 for the morning teaching shift

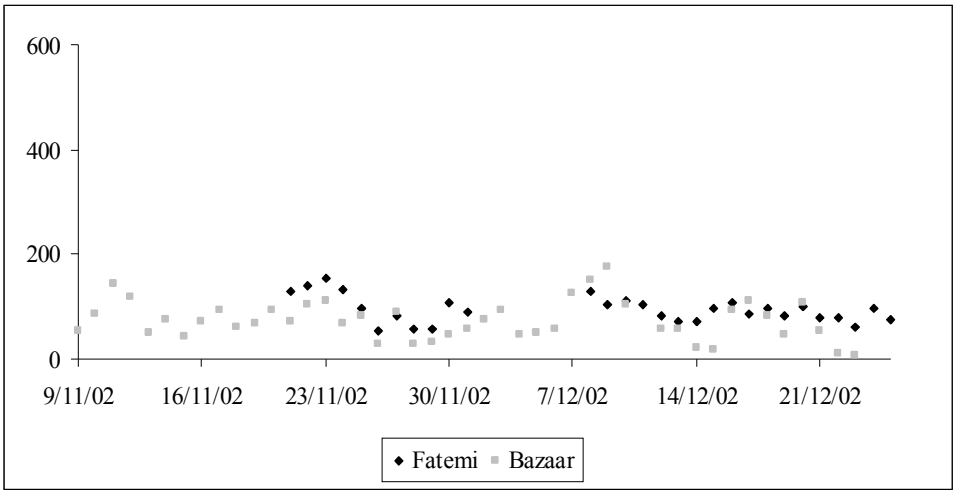

Figure 5. Daily NO levels over six-week, units in μg/m^3 for the afternoon teaching shift

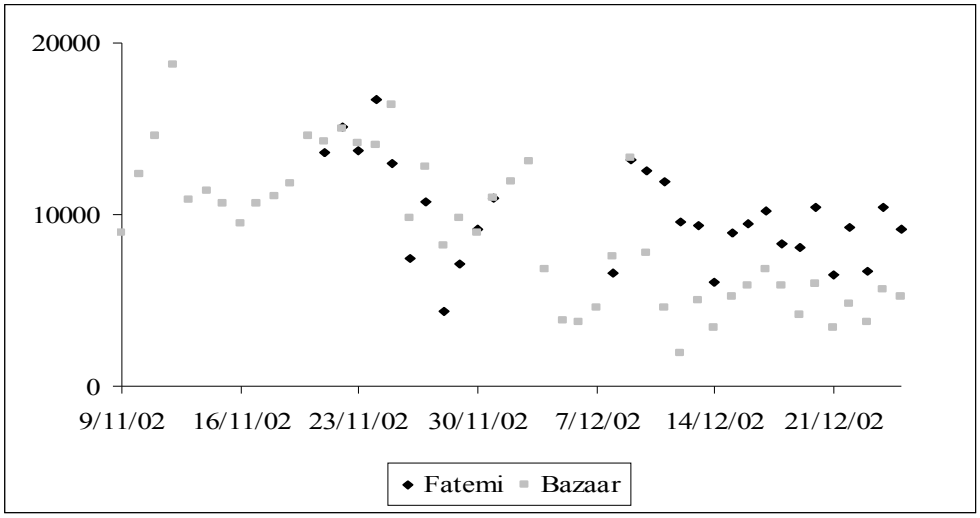

Figure 6. Daily CO levels over six-week, units in μg/m^3 for the morning teaching shift

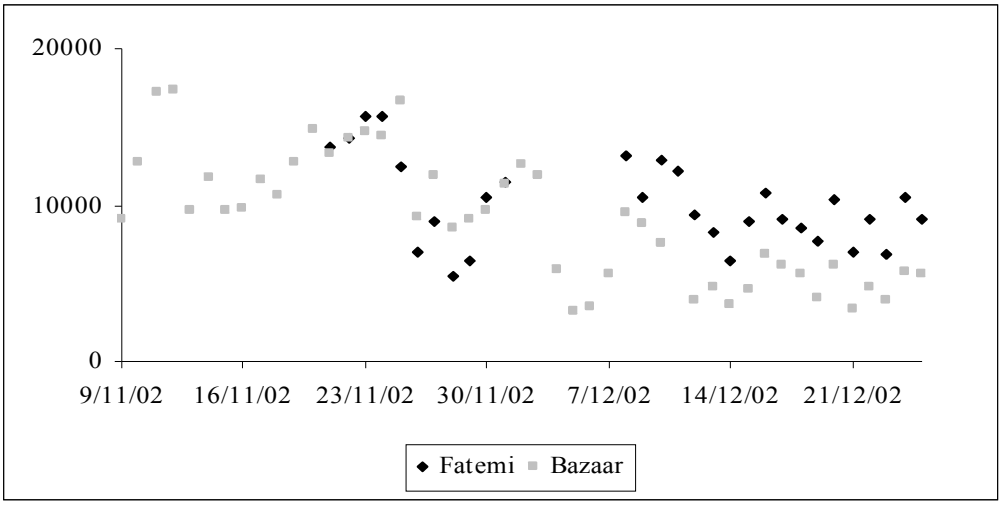

Figure 7. Daily CO levels over six-week, units in μg/m^3 for the afternoon teaching shift

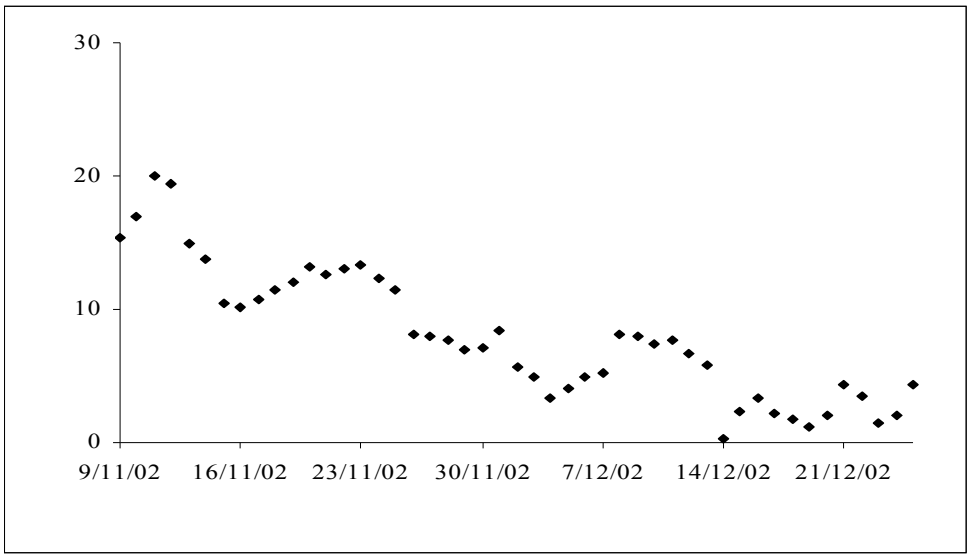

Figure 8. Daily temperature levels over six-week, units in °C

DISCUSSION

This study examined the association between air pollutants and poor lung function in elementary school children in District 12 of Tehran over six-week. In total, 562 students from two schools participated in the lung function study. For the case-crossover analysis used here, the number of cases was rather less than the number of students. The final analysis also omitted those cases for which the pollution data were missing on the relevant days. That is 158 and 375 observation were used from 210 and 498 observation read using students' predicted values and best blow respectively.

This study has shown a statistically significant relationship between outdoor air pollution and child's poor lung function. In this study, associations of seven-day moving averages of PM_{10}, NO and CO with poor lung function were found. However, the relationship between the rest of air pollutants and child's poor lung function has not shown up may be because of their many missing values. While the frequency of poor lung function was high in December, this study showed the effect of NO concentration could increase the number of days with poor lung function. In other hand, higher concentration of NO is associated with higher rate poor lung function.

Nitric oxide (NO) is the most common form of nitrogen directly emitted into the atmosphere.[1] In ambient outdoor air, nitric oxide (NO), which is emitted by motor vehicles, combines with oxygen in the atmosphere under the action of sunlight, producing nitrogen dioxide (NO_2) a major air pollutant and other NO_X. The previous studies showed nitric oxide does not significantly affect human health. On the other hand, elevated levels of NO_2 cause damage to the mechanism that protect the human respiratory tract and can increase a person's susceptibility to respiratory infections.[13,14]

In particular populations living near busy roads, NO_2 is of particular concern. At levels currently observed in Europe, exposure to NO_2 may decrease lung function[15] and increase the risk of respiratory problems, particularly in children.[16] Short-term exposure to peak levels can increase respiratory allergic reactions.

Overall, the study had good response rates with a response of 72%. Therefore, it can be considered representative for the busier areas of Tehran at least. To assure consistency in the measurements of lung function, the researcher used competition between students to get their best PEFR. The students were blinded to the hypothesis investigated in this study. One reason was that they could not check out the air pollution level every day as it was not available everywhere. It was presented every day on an electronic screen on Fatemi station only at the time were the data were collected and it was available online but the number of students who had access to internet was limited. Another reason was that the population did not express much concern about the level of air pollution. A possible confounder that was not controlled for in the analysis was the use of asthma medication. However, only 10 students in that sample used this medication. The effect of this confounder would be to limit our ability to detect an effect, as it would potentially mask the effect of air pollution on lung function. Therefore, it is expected that selection and respondents bias have not substantially influenced the results of this study.

As a form of case-control was used in the analysis, a selection bias might be of concern in the selection of the controls. To prevent this, a symmetric bidirectional method was used; this was described as providing adequate control.[17]

Thus, this study has shown strong and consistent associations between children's poor lung function and outdoor air pollutants in District 12 of Tehran for some pollutants. The strong association found in this study was an increase in seven-day moving average of NO using both definitions. These impacts also appeared to be distinct from any temperature effects. PM_{10} and CO are not consistent with the literature. To answer the study question whether there is an association between air pollution levels and poor lung function, the study showed there is association between lung function changes or airway obstruction with air pollution levels. These data indicate that in circumstances in which NO levels are chronically elevated, the levels of exposure to NO in the previous seven-day can influence the level of lung function in children. Interestingly, other study on absenteeism also showed the positive association between the concentration of NO and respiratory related absenteeism from school.[12] This study adds the effect and positive association of NO on lung function.

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