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Effect of Air Pollutants and Environmental Noise on the Childhood Asthma Prevalence in Tehran, Iran

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ABSTRACT

The purpose of this study is to investigate the effect of air pollutants and noise on the prevalence of childhood asthma in Tehran, Iran.

The standardized questionnaire was completed by one of the parents of children aged 6–7 years or by adolescents aged 13–14 years.

The asthma prevalence in ages 6-7 and 13–14 was found to be 8.8% and 17.44%, respectively. A significant positive association was observed between "ever wheezing" and monoxide carbon (CO) concentration (OR=1.84, 1.05-3.25 in 13–14 years), the occurrence of 4 to 12 wheezing attacks and sulfur dioxide (SO_2) concentration (Odds Ratio [OR]=1.39, 1.04-1.91) and particulate matter less than 2.5 micron ($PM_{2.5}$) concentration (OR=1.38, 1.05-1.98 and OR=1.13, 0.98-1.39 in 6-7 and 13–14 years, respectively), as well as one night per week of sleep disturbances and nitrogen dioxide (NO_2) concentration (OR=1.09, 1.03-1.16 in 6–7 years, respectively). It was also found that there was a significant interaction between the noise level and particulate matter less than 10 microns (PM_{10}) level.

Based on the findings, exposure to certain outdoor air pollutants and noise can affect the prevalence of asthma symptoms in residents of Tehran. The simultaneous presence of air pollutants and noise has an aggravating effect on the prevalence of asthma symptoms. Therefore, controlling sources of pollutants for reducing asthma symptoms is suggested.

Keywords: Air pollution; Asthma; Environmental noise; Pediatrics

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INTRODUCTION

Asthma affects more than 300 million people worldwide.[1] It is a multifactorial disease and the most common chronic respiratory disease in children, with significant costs due to healthcare utilization, morbidity, and mortality.[2] Genetic basis, lifestyle, epigenetics, and environmental stressors have been identified as risk factors for asthma.[1] Outdoor air pollutants, particularly particulate matter less than 2.5 microns ($PM_{2.5}$), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), have been associated with the onset and exacerbation of asthma.[3,4] Road noise, one of the environmental stressors, can exacerbate asthma through its effect on the immune system, potentially producing oxidative stress and releasing stress hormones such as cortisol. These disruptions can potentially cause respiratory diseases such as asthma and have an aggravating effect on the prevalence of asthma symptoms.[5] Different results have been reported in various studies regarding the association between exposure to air pollutants, traffic noise, and asthma prevalence across different age groups.[1,2,5-11] In this study, we investigated the effects of exposure to air pollutants and environmental noise on the prevalence of childhood asthma in Tehran, Iran. To the best of our knowledge, this is the first study to assess the relationship between air pollution, road noise, and childhood asthma in Tehran. Tehran, one of the most polluted cities in the world, is the capital of Iran and the largest megacity in the Middle East.[4,10] In many studies, the concentration measured at monitoring stations serves as the basis for calculating the level of exposure. In the present study, we tried to evaluate a more exact exposure to the pollutants by calculating the concentration of air pollutants and noise levels precisely at the exposure points, especially in schools, while considering the distance between schools and the monitoring stations.

MATERIALS AND METHODS

Study Population

Participants in the age groups of 6-7 and 13–14 years, considering the recommended of International Study of Asthma and Allergic in Childhood (ISAAC) questionnaire, that at least one year lived in Tehran (35˚ 70′ 66.00″ N, 51˚ 39′ 38.55″ E) were included in the current study (Figure 1). The participants with other chronic respiratory diseases were excluded from this study. Sampling was done according to the method used in a previous study.[12] Briefly, a randomized multistage stratified cluster sampling method was used. Clusters of 20 individuals were selected to achieve an adequate sample size in each cluster. Finally, 902 individuals aged 6–7 years and, 1118 individuals aged 13–14 years in 108 schools were enrolled in the present study. The sample size was defined considering a 95% confidential interval and a 3% precision level.

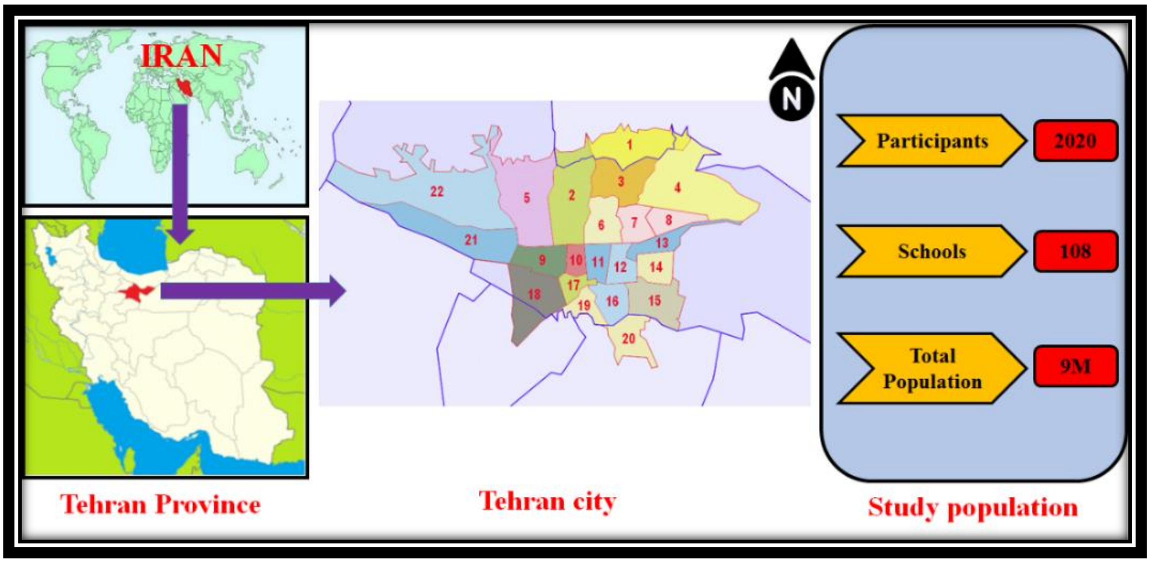

Figure. 1. Study area

Exposure Assessment to Air Pollutants and Road Noise

The mean concentrations of six criteria air pollutants, including O3, monoxide carbon (CO), NO2, SO2, particulate matter less than 10 microns (PM_{10}), and PM2.5, as well as the levels of daily noise related to the time period of investigation for asthma symptoms, were obtained from the 22 air monitoring stations and 32 noise level monitoring stations in Tehran, belonging to the Tehran Air Quality Control Company (TAQCC). Missing data in the TAQCC dataset were estimated using the Rückerl et al, method.[13,14] Individual exposure to air pollution and road noise levels was assessed based on their levels at schools using the geographic information system (GIS) in the Arc GIS 10.1 software. The ordinary kriging (OK) method was applied, taking into account the distance between each school and the monitoring stations.[15] The root mean square error (RMSE) index of 40% to 70% confirmed the validity of the OK method.[10,16]

Statistical Analysis

The data were analyzed using R software, Version 4.2.3. Demographic characteristics of the participants and the prevalence of asthma symptoms were reported as numbers and percentages. Descriptive statistics, including minimum, maximum, percentile, median, and mean ± standard deviation (SD), were used to illustrate the concentrations of air pollutants and noise levels (dBA). The association between exposure to air pollutants, road noise, and asthma symptoms was assessed through multiple logistic regression. Results were reported as odds ratios (OR) with a 95% confidence interval (CI). The interaction between air pollutants and noise was investigated via multiple linear regression. A significance level was defined as a *p value*<0.05. Spatial variations of air pollutants and noise levels were displayed in Arc GIS 10.3.

RESULTS

The demographic features of pediatrics in the current study are presented in Table 1. The ratio of males and females in the 2020 participants was almost equal (50.24% and 49.75%). Parents with an intermediate level of education (46.94%) and male passive smokers (52.87%) were predominant. The asthma prevalence in the total population was 13.21% (n=269), with a significantly higher rate of 17.44% (n=195) in the 13–14 age group compared to 8.2% (n=74) in the 6–7 age group ($p < 0.001$). When comparing genders, the prevalence of asthma was significantly higher in females (7.61%, n=155) than in males (5.60%, n=114) (p=0.004). According to the demographic features of the participants (Table 1), the prevalence of passive smokers among the participants aged 6-7 and 13–14 years old was found to be 12% (n=258) and 11% (n=230), respectively.

The rank of asthma symptoms in this study was as follows:

1. Nocturnal dry cough in the last 12 months (17.58%, n=358)
2. Exercise-induced wheezing (16.31%, n=332)
3. wheezing ever (13.80%, n=281)
4. Asthma (13.21%, n=269)
5. Wheezing in the last 12 months (9.43%, n=192)
6. 1-3 wheezing attacks in the last year (7.86%, n=160)
7. Asthma ever (6.14%, n=125)
8. Speech-limiting wheezing (2.95%, n=60)
9. Sleep disturbance 1 night per week (2.55%, n=52)
10. 4-12 wheezing attacks in the last year (1.03%, n=21)
11. Sleep disturbance of more than 12 attacks in a week (0.83%, n=17)
12. More than 12 wheezing attacks in the last year (0.64%, n=13)
13. Severe asthma (0.15%, n=3).

In assessing the relationship between the independent variables—exposure to cigarette smoke and the education level of parents—and the prevalence of asthma, a significant positive relationship was observed between exposure to cigarette smoke and asthma prevalence in all students (OR=1.35, 1.04-1.75) as well as in those aged 13 to 14 years (OR=1.58, 1.16-2.16).

The exposure level to the air pollutants was assessed by considering those pollutant concentrations at the schools, and the statistical description is shown in Table 2. Based on the exposure level to the air pollutants by considering those pollutant concentrations at the schools in Table 2, the minimum and maximum mean concentrations were related to CO at 2.68±0.32 ppb and PM10 at 72.13±18.44 µg/m3, respectively.

Road noise exposure was estimated based on the noise levels at the schools. The descriptive analysis of road noise levels during the year prior to the study is shown in Table 2. Road noise exposure was estimated based on the noise levels at the schools. The minimum and maximum daily noise exposure during the study period were found to be 57.90 and 76.10 dBA, respectively.

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Spatial variations in exposure levels to the air pollutants are illustrated in Figure 2. Spatial trends in exposure levels to noise (dBA) during the study are illustrated period in Figure 2.

Table 1. The demographic features of the participants

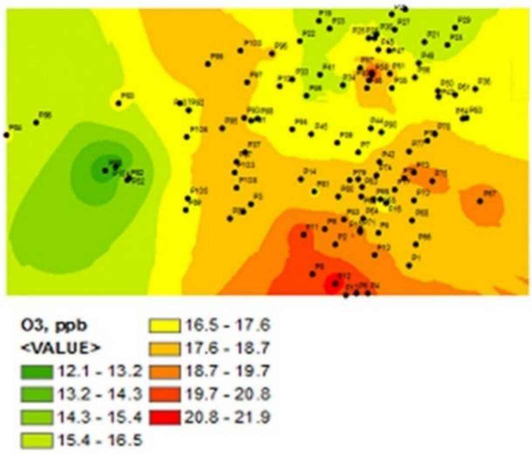
Characteristics	**Age groups**		
	n (%)	**6-7 years old, n (%)**	**13-14 years old, n (%)**
Gender			
Male	1015 (50.24)	528 (58.54)	487 (43.56)
Female	1005 (49.75)	374 (41.46)	631 (56.44)
Paternal educational level			
Low [a]	371 (18.43)	178 (19.73)	193 (17.37)
Intermediate [b]	945 (46.94)	425 (47.12)	520 (46.80)
High [c]	697 (34.62)	299 (33.15)	398 (35.82)
Maternal educational level			
Low [a]	315 (15.65)	151 (16.74)	164 (14.76)
Intermediate [b]	1094 (54.35)	498 (55.21)	596 (53.65)
High [c]	604 (30.00)	253 (28.05)	351 (31.59)
Passive smoking			
Male	258 (52.87)	113 (43.80)	145 (63.04)
Female	230 (47.13)	145 (56.20)	85 (36.96)

a Low educational level: primary school, b Intermediate educational level: high school and associated degree, c high educational level: bachelor's, master's, and doctorate degrees.

Table 2. Statistical description of the air pollutant and road noise levels at the schools during the study period

Statistics	**O3 ppb**	**CO ppm**	**NO2 ppb**	**SO2 ppb**	**PM 10 µg/m3**	**PM 2.5 µg/m3**	**Noise (dBA)**
Minimum	12.16	1.84	30.90	11.12	28.00	1.08	57.90
25th percentile	16.62	2.45	42.53	15.65	63.24	26.40	67.90
Median	17.49	2.80	49.87	16.64	76.93	29.71	69.10
Mean	17.55	2.68	50.90	16.42	72.13	28.27	69.52
75th percentile	18.31	2.88	56.76	17.49	86.92	32.07	72.00
Maximum	21.90	3.47	86.92	21.51	103.62	38.79	76.10
Standard deviation	1.45	0.32	10.56	1.70	18.44	6.57	3.76

O_3: Ozone; CO: carbon monoxide; NO_2: nitrogen dioxide; SO_2: sulfur dioxide; PM_{10}: particulate matter less than 10 microns; $PM_{2.5}$: particulate matter less than 2.5 microns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13.2 - 14.3
14.3 - 15.4
15.4 - 16.5
16.5 - 17.6
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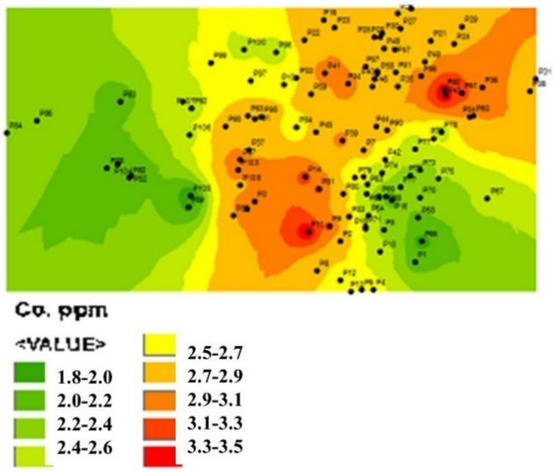
18.7 - 19.7
19.7 - 20.8
20.8 - 21.9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2.2-2.4
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2.5-2.7
2.7-2.9
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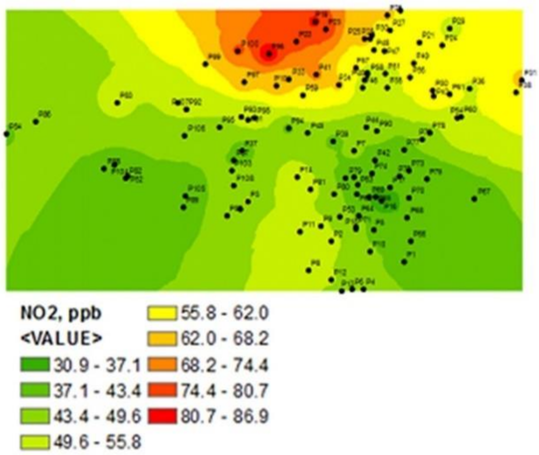
3.1-3.3
3.3-3.5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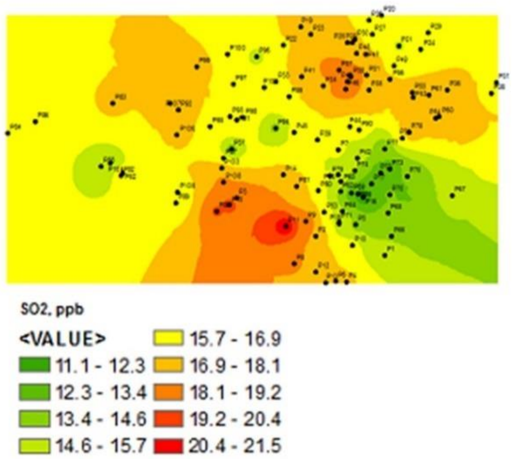
37.1 - 43.4
43.4 - 49.6
49.6 - 55.8
55.8 - 62.0
62.0 - 68.2
68.2 - 74.4
74.4 - 80.7
80.7 - 86.9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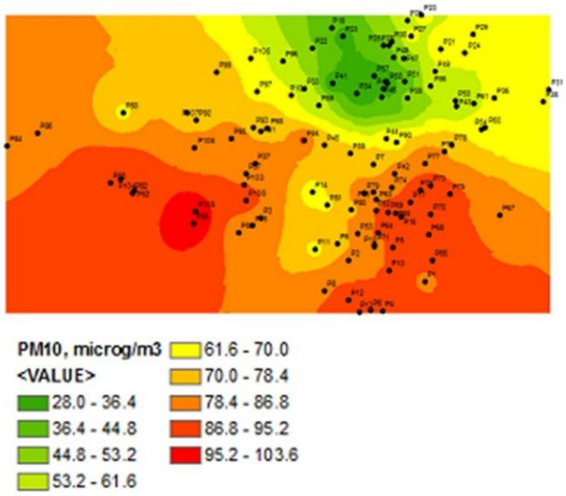
14.6 - 15.7
15.7 - 16.9
16.9 - 18.1
18.1 - 19.2
19.2 - 20.4
20.4 - 21.5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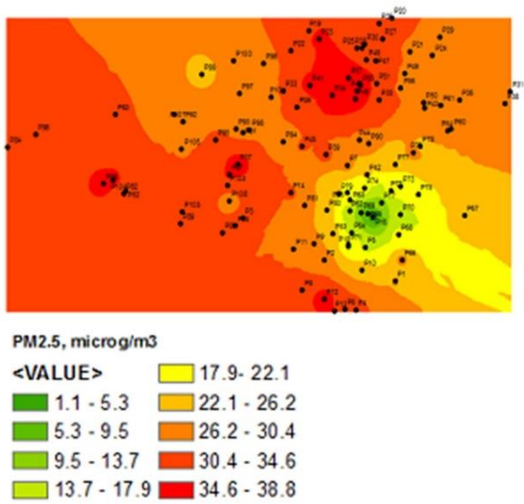
44.8 - 53.2
53.2 - 61.6
61.6 - 70.0
70.0 - 78.4
78.4 - 86.8
86.8 - 95.2
95.2 - 103.6


PM2.5, microg/m3
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5.3 - 9.5
9.5 - 13.7
13.7 - 17.9
17.9- 22.1
22.1 - 26.2
26.2 - 30.4
30.4 - 34.6
34.6 - 38.8

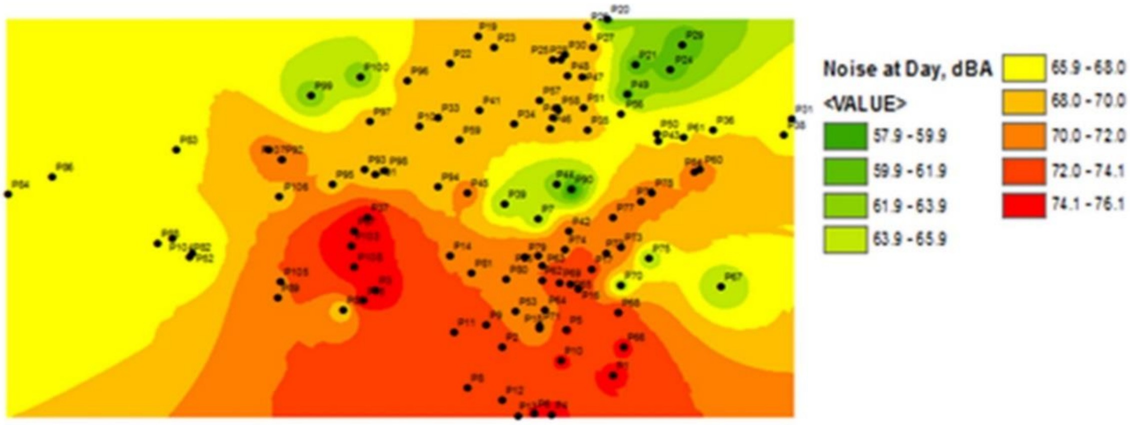

Figure 2. Spatial variations in exposure level to the air pollutants, the spatial trend of exposure level to the noise (dBA); O_3: Ozone; CO: carbon monoxide; NO_2: nitrogen dioxide; SO_2: sulfur dioxide; PM_{10}: particulate matter less than 10 microns; $PM_{2.5}$: particulate matter less than 2.5 micron

The association between air pollutant levels, daily noise level, and asthma symptoms is reported in Table 3. Although there was a significant statistical relationship between asthma prevalence and the concentration of air pollutants during the studied period in the total population, the odds ratio (OR) value was not significant and close to one. In examining other asthma symptoms, an OR greater than one indicated a significant relationship between ‘wheezing ever’ and CO concentration (OR=1.52, 1.01-2.30), wheezing attacks 4 to 12 times in the last year and SO2 concentration (OR=1.39, 1.04-1.91) as well as PM2.5 concentration (OR=1.19, 1.04-1.40), and sleep disturbances one night per week and NO2 concentration (OR=1.03, 1.00-1.06). An investigation of the association in the 6 to 7-year-old participants showed that there was an OR greater than 1 and a significant association between chronic asthma and NO2 concentration (OR=1.03, 1.00-1.05), asthma and NO2 concentration (OR=1.02, 1.00-1.04), wheezing attacks 1 to 3 times per year and PM10 concentration (OR=1.03, 1.00-1.07), wheezing attacks 4 to 12 times per year and PM2.5 concentration (OR=1.38, 1.05-1.98), sleep disturbances one night per week and concentrations of CO (OR=4.27, 1.04-6.15) and NO2 (OR=1.09, 1.03-1.16), as well as nocturnal dry cough and NO2 concentration (OR=1.01, 1.00-1.03) and PM2.5 concentration (OR=1.04, 1.00-1.08). In the 13–14-year-old population, there was an OR greater than one and a significant association between regular wheezing and CO concentration (OR=1.84, 1.05-3.25) and wheezing attacks 4–12 times a year and O3 concentration (OR=1.74, 1.00-3.15). The relationship between the daily noise level (dBA) and asthma symptoms showed a significant positive association between noise and asthma (Table 3). In order to investigate the exacerbating effect of two investigated parameters on the prevalence of asthma, the interaction between noise pollution and the concentration of air pollutants was evaluated using a multiple linear regression model. Results are reported in Table 4. However, there was not a significant association between the PM10 concentration and asthma prevalence, and noise and asthma prevalence, but it was significant the interaction between noise and the PM10 concentration in asthma prevalence (*p*=0.03).

Table 3. Association between air pollutant levels and noise and asthma symptoms in total and different age groups reported as odds ratios (OR) with 95% confidence interval (CI)

Asthma symptoms			O3	CO	NO2	SO2	PM10	PM2.5	Noise
Asthma ever		Total	0.84(0.74-0.96)*	1.21(0.672.22)	1.00(0.98-1.02)	0.92(0.83-1.03)	0.99(0.98-1.00)	0.99(0.96-1.02)	0.97(0.92-1.02)
		6-7years	0.83(0.65–1.07)	1.44(0.48-.57)	1.03(1.00-1.05)*	0.91(0.70-1.18)	0.99(0.97-1.01)	0.98(0.92-10.7)	0.98(0.89-1.08)
		13-14years	0.86(0.74-1.00)*	1.09(0.54-2.27)	0.99(0.97-1.01)	0.92(0.81-1.05)	0.99(0.98-1.00)	0.99(0.96-1.02)	0.96(0.92-1.02)
Wheezing ever		Total	0.84(0.77-0.93)*	1.52(1.01–2.30)*	1.00(0.99-1.01)	1.01(0.94-1.10)	0.99(0.98-1.00)	1.00(0.98-1.02)	1.01(0.97-1.05)
		6-7years	0.92(0.80-1.06)	1.17(0.64-2.17)	1.01(0.99-1.03)	1.05(0.92-1.21)	0.99(0.98-1.00)	1.01(0.97-1.05)	0.99(0.93-1.04)
		13-14years	0.81(0.72-0.91)*	1.84(1.05-3.25)*	0.99(0.98-1.01)	0.99(0.90-1.11)	0.99(0.98-1.00)	0.99(0.97-1.02)	1.03(098-1.08)
Wheezing in the last 12 months		Total	0.88(0.72-1.07)	0.40(0.18-0.85)*	1.00(0.98-1.03)	0.95(0.82-1.10)	1.00(0.98-1.01)	1.00(0.97-1.04)	0.98(0.91-1.05)
		6-7years	0.94(0.71-1.24)	0.69(0.24-1.98)	1.00(0.97-1.04)	0.94(0.69-1.26)	1.00(0.97-1.02)	0.98(0.89-1.08)	0.92(0.80-1.04)
		13-14years	0.82(0.60-1.10)	0.2(0.06-0.61)*	1.00(0.97-1.03)	0.94(0.77-1.13)	1.00(0.98-1.02)	1.00(0.96-1.05)	1.01(0.93-1.09)
Asthma (wheezing in the last year or asthma ever)		Total	0.85(0.77-0.94)*	1.11(0.73-1.69)	1.00(0.99-1.01)	1.00(0.92-1.09)	0.99(0.98-1.00)	1.00(0.98-1.03)	0.98(0.95-1.02)
		6-7years	1.00(0.85-1.18)	1.19(0.61-2.37)	1.02(1.00-1.04)*	1.09(0.94-1.27)	0.99(0.97-1.00)	1.02(0.97-1.07)	0.97(0.92-1.04)
		13-14years	0.79(0.70-0.89)*	1.02(0.59-1.75)	0.99(0.98-1.01)	0.96(0.87-1.07)	0.99(0.98-1.000)	1.00(0.98-1.03)	0.99(0.95-1.04)
Wheezing attacks	1-3 attacks	Total	0.87(0.65-1.14)	0.46(0.14-1.35)	0.96(0.93-1.00)	0.85(0.66-1.07)	1.03(0.99-1.04)	0.94(0.86-1.01)	1.00(0.90-1.10)
		6-7years	1.03(0.72-1.45)	0.45(0.09-2.07)	0.96(0.90-1.01)	1.02(0.66-1.62)	1.03(1.00-1.07)*	0.93(0.79-1.06)	1.11(0.94-1.32)
		13-14years	0.69(0.43-1.14)	0.50(0.08-2.30)	0.97(0.92-1.02)	0.79(0.54-1.10)	1.01(0.98-1.04)	0.94(0.83-1.03)	0.94(0.81-1.08)
	4-12 attacks	Total	1.28(0.92-1.82)	2.52(0.67-10.01)	1.02(0.97-1.06)	1.39(1.04-1.91)*	0.98(0.95-1.00)	1.19(1.04-1.40)*	1.12(0.98-1.30)
		6-7years	1.05(0.67-1.66)	2.29(3.06-18.70)	1.04(0.97-1.11)	1.16(0.68-1.95)	0.95(0.90-0.99)*	1.38(1.05-1.98)*	0.99(0.80-1.26)
		13-14years	1.74(1.00-3.15)*	2.40(0.40-3.70)	1.00(0.94-1.07)	1.47(0.98-2.40)	1.00(0.97-1.04)	1.13(0.98-1.39)	1.16(0.98-1.43)
	More than 12 attacks	Total	0.94(0.64-1.44)	1.38(0.27-7.36)	1.04(0.97-1.10)	0.85(0.61-1.23)	0.97(0.93-1.02)	0.97(0.90-1.07)	0.87(0.75-1.00)*
		6-7years	0.88(0.54-1.51)	1.48(0.16-1.26)	1.03(0.95-1.12)	0.71(0.31-1.48)	0.99(0.94-1.04)	0.94(0.78-1.13)	0.80(0.60-1.01)
		13-14years	0.93(0.44-2.08)	0.88(0.61-1.01)	1.07(0.98-1.16)	0.85(0.51-1.55)	0.97(0.92-1.01)	0.97(0.87-1.13)	0.89(0.72-1.13)

Table 3. Continued...

Asthma symptoms			O3	CO	NO2	SO2	PM10	PM2.5	Noise
Sleep disturbance	1 night per week	Total	0.82(0.65-1.03)	1.55(0.60-3.99)	1.03(1.00-1.06)*	0.96(0.80-1.16)	0.96(0.95-0.99)*	1.03(0.98-1.09)	0.98(0.90-1.05)
		6-7years	0.84(0.60-1.14)	4.27(1.04-6.15)*	1.09(1.03-1.16)*	1.21(0.82-1.82)	0.95(0.92-0.98)*	1.09(0.96-1.26)	0.94(0.81-1.09)
		13-14years	0.75(0.52-1.04)	0.70(0.2-2.64)	1.00(0.96-1.04)	0.89(0.69-1.15)	0.99(0.96-1.01)	1.02(0.96-1.09)	1.02(0.90-1.16)
	>1 night per week	Total	1.03(0.73-1.47)	0.22(0.05-0.86)*	0.95(0.89-1.01)	0.75(0.57-0.98)*	0.98(0.95-1.02)	1.01(0.90-1.19)	0.92(0.81-1.06)
		6-7years	1.07(0.66-1.87)	0.09(0.03-1.02)	0.89(0.75-1.00)	0.37(0.13-0.83)*	1.02(0.97-1.08)	0.93(0.78-1.12)	0.83(0.64-1.04)
		13-14years	0.98(0.59-1.70)	0.31(0.52-2.01)	0.97(0.90-1.03)	0.82(0.58-1.18)	1.00(0.97-1.05)	0.94(0.87-1.01)	0.98(0.83-1.19)
Speech-limiting wheezing		Total	1.04(0.81-1.33)	1.16(0.47-2.96)	1.00(0.97-1.03)	0.94(0.79-1.13)	0.99(0.98-1.01)	0.98(0.94-1.03)	0.94(0.96-1.01)
		6-7years	1.24(0.87-1.84)	3.72(0.80-6.18)	1.03(0.97-1.08)	1.13(0.74-1.76)	0.99(0.95-1.02)	0.99(0.87-1.13)	0.82(0.67-0.97)*
		13-14years	0.84(0.59-1.19)	0.61(0.19-1.94)	1.00(0.96-1.03)	0.87(0.70-1.09)	1.00(0.98-1.02)	0.97(0.93-1.02)	0.98(0.89-1.08)
Severe asthma		Total	1.15(0.56-2.38)	1.2(1.03-1.49)	1.0(0.92-1.11)	1.15(0.59-2.22)	0.95(0.89-1.01)	1.20(0.94-1.73)	0.71(0.50-0.93)*
		6-7years	1.56(0.59-4.37)	3.53(0.57-5.98)	1.02(0.89-1.13)	1.40(0.56-3.43)	0.94(0.86-1.01)	1.36(0.94-2.52)	0.75(0.48-1.06)
		13-14years	0.71(0.27-2.88)	0.68(0.56-0.97)	1.06(0.86-1.25)	1.06(0.41-9.50)	0.96(0.85-1.10)	1.11(0.85-2.04)	0.65(0.22-1.03)
Exercise-induced wheezing		Total	0.85(0.78-0.94)*	1.02(0.69-1.52)	0.99(0.98-1.00)	0.95(0.88-1.03)	0.99(0.98-1.00)	0.99(0.97-1.01)	0.97(0.94-1.00)
		6-7years	1.0(0.85-1.20)	0.88(0.44-1.80)	1.00(0.97-1.02)	1.01(0.86-1.20)	0.99(0.98-1.00)	1.00(0.95-1.05)	0.93(0.87-0.99)*
		13-14years	0.82(0.74-0.91)*	1.05(0.66-1.70)	0.99(0.97-1.00)	0.93(0.85-1.02)	1.00(0.99-1.00)	0.98(0.96-1.01)	0.98(0.95-1.02)
Nocturnal dry cough in the last 12 months		Total	0.97(0.89-1.05)	0.84(0.59-1.21)	1.00(0.98-1.01)	0.98(0.92-1.06)	0.99(0.98-1.00)*	1.0(0.98-1.02)	0.97(0.94-1.00)
		6-7years	0.92(0.82-1.05)	0.80(0.47-1.37)	1.01(1.00-1.03)*	1.06(0.94-1.20)	0.98(0.97-0.99)*	1.04(1.00-1.08)*	0.98(0.93-1.03)
		13-14years	1.03(0.92-1.15)	0.88(0.54-1.46)	0.98(0.97-1.00)	0.95(0.87-1.05)	0.99(0.98-1.00)	0.98(0.96-1.00)	0.97(0.93-1.01)

O_3: Ozone; CO: monoxide carbon; NO_2: nitrogen dioxide; SO_2: sulfur dioxide; PM_{10}: particulate matter less than 10 micron; $PM_{2.5}$: particulate matter less than 2.5 microns

Adjusted analysis for gender, age, and smoking, *The *p* values less than 0.05.

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Table 4. *p* values of interaction between levels of air pollutants and noise for each asthma symptom

Asthma symptoms		O3	CO	NO2	SO2	PM10	PM2.5
	Asthma ever						
	Noise	0.73	0.09	**0.02**	0.81	**0.03**	**0.03**
	Wheezing ever						
	Noise	0.83	0.13	0.14	0.32	**0.002**	0.26
	Wheezing in the last 12 months						
	Noise	0.50	0.09	0.95	0.09	0.19	0.62
	Asthma (wheezing in the last year or asthma ever)						
	Noise	0.46	0.41	0.19	0.21	**0.03**	0.07
Wheezing attacks	1-3 attacks						
	Noise	0.34	0.47	0.08	0.37	0.25	0.42
	4-12 attacks						
	Noise	0.15	0.89	0.76	0.47	0.21	0.99
	More than 12 attacks						
	Noise	0.72	0.20	**0.02**	0.64	0.84	0.21
Sleep disturbance	1 night per week						
	Noise	0.24	0.23	0.91	0.11	0.86	0.17
	>1 night per week						
	Noise	0.39	0.81	0.89	0.17	0.79	0.29
	Speech-limiting wheezing						
	Noise	0.20	0.67	0.22	0.24	0.15	0.66
	Severe asthma						
	Noise	0.06	0.22	**0.04**	0.91	**0.03**	0.16
	Exercise-induced wheezing						
	Noise	0.09	0.80	0.69	**0.03**	0.07	0.29
	Nocturnal dry cough in the last 12 months						
	Noise	0.24	**0.05**	0.65	**0.002**	**0.05**	**0.01**

The bold p *values* are statistically significant. O_3: Ozone; CO: carbon monoxide; NO_2: nitrogen dioxide; SO_2: sulfur dioxide; PM_{10}: particulate matter less than 10 microns; $PM_{2.5}$: particulate matter less than 2.5 microns

DISCUSSION

The effect of air pollutants and environmental noise on childhood asthma prevalence in Tehran, Iran has been investigated in this study. According to the results, the asthma prevalence in the 13–14 age group was significantly higher than in the 6 to 7 age group (p<0.001).

It is consistent with Fazlollahi et al.'s study regarding asthma among children and adolescents in the whole of Iran as 12.4% and 9.4% for 13–14 and 6–7 years old, respectively.[12]

In the current study, the prevalence of asthma in females was significantly higher than in males. The prevalence of asthma in Iranian male students in the study of Fazlollahi et al, was significantly (p<0.001) higher than that of female students,[12] which is not consistent with the results of the current study. In the study conducted by Fazlollahi et al, on asthma prevalence in 31 provinces of Iran., the prevalence of

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asthma in males was higher than that of females, with a significant difference (p=0.002).[17]

According to the demographic features of the participants in Table 1, the prevalence of passive smokers among the participants aged 6-7 and 13–14 years old was found to be similar. In a study conducted in 31 provinces of Iran during the same period as our study, 13.4% of children aged 6 to 7 and 14.6% of people aged 13 to 14 with asthma were exposed to cigarette smoke. A significant relationship was identified between exposure to cigarette smoke and the prevalence of asthma and severe asthma in both age groups.[12] However, in the current study, no significant association was observed between the education level of parents and the prevalence of asthma. In the study by Fazlollahi et al in 31 provinces of Iran, a significant relationship was found between and maternal education level the prevalence of asthma, whereas no significant relationship was identified between paternal education level and asthma.[12]

TAQCC reported that PM10 concentrations at all stations during the study period exceeded the national standard levels. Spatial and temporal levels of CO from March 2014 to March 2016 were found to be in a desirable range.[18,19]

WHO and Iran's national standards set the maximum permissible level of outdoor daily noise in residential and educational areas at 55 dBA.[20,21] The mean daily noise exposure level during this period was 69.52± 3.76 dBA. Therefore, the mean noise level in the studied schools during the study period was 10 dBA higher than the defined standard.

Spatial variations in exposure levels to the air pollutants illustrated in Figure 2a showed that the concentrations of O_3 had a wide spatial trend from 12.10 to 21.90 ppb. An extreme concentration of O3 was detected in the southern parts of Tehran. In the troposphere layer, O3 as a secondary pollutant, is produced as the result of the combination of precursors (volatile organic compounds (VOCs) and NO2) and sunlight as a catalyst. Based on the spatial trend of NO2 in Figure 2a. its concentration in the southern parts of Tehran was lower than in other areas. Consequently, higher concentrations of O3 in southern parts could be due to stronger sunlight in these areas, as reported by TAQCC.[19,20]

In addition, higher concentrations of O3 in the southern parts of Tehran could be associated with VOCs released from vehicle traffic on highways located in this region. The concentration of CO varied between 1.8 and 3.5 ppm. The maximum concentration was found in schools located in the northeast and south of Tehran. According to the annual air quality report, the CO level in Tehran during the study period was below the national standards.[18,19] NO2 concentration varied between 30.90 and 86.90 ppb. The highest concentration of NO2 was observed in the northern region of Tehran. In the TAQCC report during the study period, the highest NO2 values were reported in the northern and northwestern areas due to the high traffic volume, especially from heavy vehicles.[18,19] The concentration of SO2 during the study period varied between 11.10 and 21.50 ppb. The maximum concentration of SO2 observed in schools located in the south of Tehran can be attributed to the presence of oil refineries, transportation highways, and heavy diesel fuel -vehicles within this area of the city. The concentration of PM_{10} varied from 28.00 to 103.60 $\mu g/m^3$. The highest concentration of PM10 is observed in the schools located in the east and west of Tehran. PM10 can be released from natural sources, and considering the prevailing wind direction in Tehran from southwest to northeast, the high concentration of PM10 in the southwestern parts, where the wind enters the city, is logical.[18] The activities of stationary sources of air pollution, such as cement factories in southern areas of Tehran are also effective in releasing PM10.[18] PM2.5 levels ranging from 1.10 to 38.80 µg/m3. Most schools, except those located in a small area in the southeastern part of the city, have high concentrations of PM2.5. Throughout most days of the year, all stations experienced unhealthy conditions regarding PM2.5 pollution. The PM2.5 pollutant is produced mostly from combustion processes, particularly from motor vehicles and urban stationary sources. Under conditions of atmospheric instability, this pollutant tends to accumulate.[18,19] According to the spatial trends in exposure levels to noise (dBA) during the study period in Figure 2b, the maximum daily noise levels were at the southern and central points in Tehran. This may be due to the presence of noisy industries, numerous highways, high population density, the existence of commercial and administrative centers, as well as railway and airport stations in these regions.[4]

The results of similar studies indicate that air pollutants can significantly affect the functioning of the respiratory system.[13,22] Based on the results reported from a study of adults living in Tehran during the same period revealed a significant relationship between the

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concentrations of CO and PM10 and the prevalence of asthma.[10] In Namvar et al.'s study on children under 7 years old in Tehran, a significant relationship was reported between the concentrations of CO, NO2, and SO2 and current asthma.[13] The differences in results may be attributed to the varying age groups and study periods.

A significant positive association was observed between noise and asthma in this study. In the study of Cai et al. in European Union countries from 2006 to 2013, noise pollution from traffic was not associated with asthma prevalence.[23] Conversely, a significant positive statistical correlation was observed in Faraji et al.'s study regarding asthma prevalence in adults and the levels of day and night noise during the present study's time frame, with OR=1.03, 0.98-1.05 and OR=1.05, 0.84-1.09, respectively.[4] Additionally, in the study of Bockelbrink et al, in Germany, it was found that noise pollution, especially at night, was associated with an increase in asthma prevalence.[24] Other similar studies have reported a significant relationship between exposure to noise pollution and asthma prevalence.[25,26]

According to the results of interaction between the noise pollution and the concentration of air pollutants, the interaction between noise and the PM10 concentration in asthma prevalence was significant. Traffic makes both noise and PM10, which exacerbates asthma as shown in numerous prior studies.[5,27,28]Additionally, a significant interaction was found between the concentration of certain pollutants and the level of noise in asthma ever, wheezing ever, wheezing attacks, exercise-induced wheezing, and nocturnal dry cough in the last 12 months.

The significant positive associations between the studied variables are reported below:

A) **NO2 concentrations**, prevalence of asthma, asthma ever, nocturnal dry cough in the 6 to 7 age group, and sleep disturbance occurring 1 night per week in both the total population and the 6 to 7 age group.

B) **CO concentration**, wheezing ever in both the total population and the 13 to 14 age group, and sleep disturbances of 1 night per week in the 6 to 7 age group.

C) **PM10 concentration** and 1-3 wheezing attacks in the 6 to 7 age group.

D) **O3 concentration** and 4–12 wheezing attacks in the 13 to 14 age group.

E) **SO2 concentration** and 4–12 wheezing attacks in the total population.

F) **PM2.5 concentration,** nocturnal dry cough in the 6 to 7 age group, and 4–12 wheezing attacks in both the total population and the 6 to 7 age group.

Therefore, it is suggested to control the sources of these pollutants to reduce asthma symptoms in children and adolescents living in Tehran. Reports indicate mobile sources- such as passenger cars, taxis, motorcycles, vans, minibusses, buses, and trucks—contribute more significantly to air pollution emissions in Tehran than stationary sources, which include industries, the domestic and commercial sectors, energy conversion facilities (power plants and refineries), terminals, and gas stations. Consequently, controlling mobile sources may effectively diminish air pollution in Tehran.

Mobile sources, along with population density and the presence of numerous commercial and administrative centers, can be considered sources of atmospheric noise in Tehran city. To reduce noise levels, the following solutions are recommended: raising public awareness about social behaviors related to noise, promoting cultural growth in traffic management, reducing the number of motor vehicles especially motorcycles, prohibiting the use of trolley trucks in the city through improved traffic engineering, disconnecting loudspeakers in public areas, encouraging greater use of bicycles, and increasing urban green spaces. Implementing these measures can help reduce noise pollution in Tehran.

STATEMENT OF ETHICS

This study was approved by the Ethics Committee of Immunology, Asthma and Allergy Research Institute (IAARI) of Tehran University of Medical Sciences under the ethics code IR.TUMS.IAARI.REC.1400.005. The participants were informed about the study before the distribution of the questionnaire.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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