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Long-term exposure to air pollution and risk of preterm birth and low birth weight in Tehran, Iran

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ABSTRACT

Introduction: Adverse effects of air pollution on human health has been identified as a major concern worldwide. We conducted this study to investigate the association between prenatal exposure to ambient air pollution and Low Birth Weight (LBW) and preterm among newborns in the megacity of Tehran.

Materials and methods: This cross-sectional study was carried out on 1605 newborns. Data on the residential locations of mothers were collected from birth certificates. To estimate the prenatal exposure to air pollutants, data of 21 air quality monitoring stations in Tehran were used. The Man-Whitney test was used to estimate the association between exposure to ambient air pollution and LBW and preterm.

Results: The mean birth weight in our analyses was 3117 g. A significant association was found between maternal exposure to particulate matter less than 2.5 µm ($PM_{2.5}$) in the first trimester and incidence of preterm ($p=0.011$) and LBW ($p=0.003$) in newborns. Also, a close association was observed between exposure to Carbon Monoxide (CO) in the first and second trimesters and LBW ($p=0.002$, $p=0.015$). There were no statistically significant associations in LBW in the case of Particulate Matter less than 10 µm (PM_{10}), Sulfur Dioxide (SO_2), and Ozone (O_3).

Conclusion: The results revealed that the higher risk for LBW was related to ambient $PM_{2.5}$ and CO. Since many factors may affect LBW, and the pathogenic mechanisms of the effect of air pollution on LBW have not been completely elucidated, the findings should be interpreted with caution and further studies need to be conducted on this issue considering the large sample size.

Introduction

Air pollution is one of the most important environmental risk factors throughout the world [1]. In recent years, the adverse effects of air pollution on human health especially vulnerable groups including the elderly, pregnant women, and children have been identified as a major concern. Some investigations revealed that air pollution can aggravate cardiovascular and respiratory

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disease [2-4]. The health effects associated with exposure to air pollutants has been demonstrated in epidemiological studies including respiratory symptoms (cough, phlegm, and wheeze), hospitalization, decreased lung function, chronic loss of pulmonary function, asthma development, and premature mortality in people with chronic lung disease [5-7]. Furthermore, studies have also increasingly shown that exposure to air pollution is associated with hypertensive disorder of pregnancy, stillbirth risk, low infant birth weight, autism, heart attack, and stroke mortality [8-13].

The assessment conducted by the World Health Organization (WHO) about the burden of disease attributed to air pollution reported that "more than 2 million premature deaths each year can be attributed to the outdoor and indoor air pollution" mostly in developing countries [14]. Air pollution can indirectly affect pregnancy outcomes but the biological mechanism has not been completely elucidated yet. However, since the growth of the fetus is affected by maternal factors, entering air pollutants into the maternal bloodstream via inhalation and absorption may interference with some processes, and it can cause disturbances in the blood circulation of the mother and lead to effects on the development of the fetuses [15]. These effects can result in delivering premature and low birth weight infants.

World health organization (WHO) has defined LBW as weight at birth of <2,500 g (5.5 pounds) [16]. Low birth weight infants are approximately 20 times more likely to die than heavier babies and it can be closely associated with neonatal mortality and morbidity, cognitive development, and chronic diseases later in life [16].

According to low birth weight regional and global estimates, more than 20 million infants are born with low birth weight globally. Asia and Africa were two regions in the developing world that the number of low birth weight babies is concentrated in. About 72% of low birth weight infants are born in Asia and 22% in Africa. The LBW infants were reported 7% (88000 infants) in Iran in 1995 by UNICEF/WHO.

Recently, many studies have indicated a relationship between Low Birth Weights (LBW), preterm birth, and Intrauterine Growth Restriction (IUGR), with exposure to poor air quality in urban and industrials [17-20]. Because of different human activities in urban areas or industrial parts, many pollutants can be released into the atmosphere which can be a hazard to human health and the environment [21-27]. The megacity of Tehran is rated as one of the most polluted cities in the world due to some reasons including traffic congestion, nearby industries, gasoline quality, geographical aspects, etc. Therefore, our analysis focused on the association between prenatal exposure to ambient air pollutants such as Particulate Matter (PM), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Nitrogen Oxides (NO_x), Nitrogen Monoxide (NO), and Ozone (O_3); and Low Birth Weight (LBW) and preterm among newborns in the megacity of Tehran.

Materials and methods

Study population

This cross-sectional study was conducted in Tehran, the capital of Iran. The samples were all the newborns from mothers who were residing in Tehran city during pregnancy with no history of pre-eclampsia, hypertension, renal, cardiopulmonary diseases, and drug consumption during pregnancy. Three hospitals affiliated to Tehran University of Medical Sciences (TUMS) were selected which geographically had located in different areas. A total of 1605 newborns were randomly selected from hospitals in different regions of Tehran city for gathering the data of LBW and preterm.

To get more information, required data was obtained from the birth certificates (medical records) in the hospitals. Some cases were excluded from the study considering some factors including chronic disease, mother's addiction, fetal chromosomal abnormalities, weight <1500 g, and children whose mothers' residential areas were unknown during pregnancy. Other risk

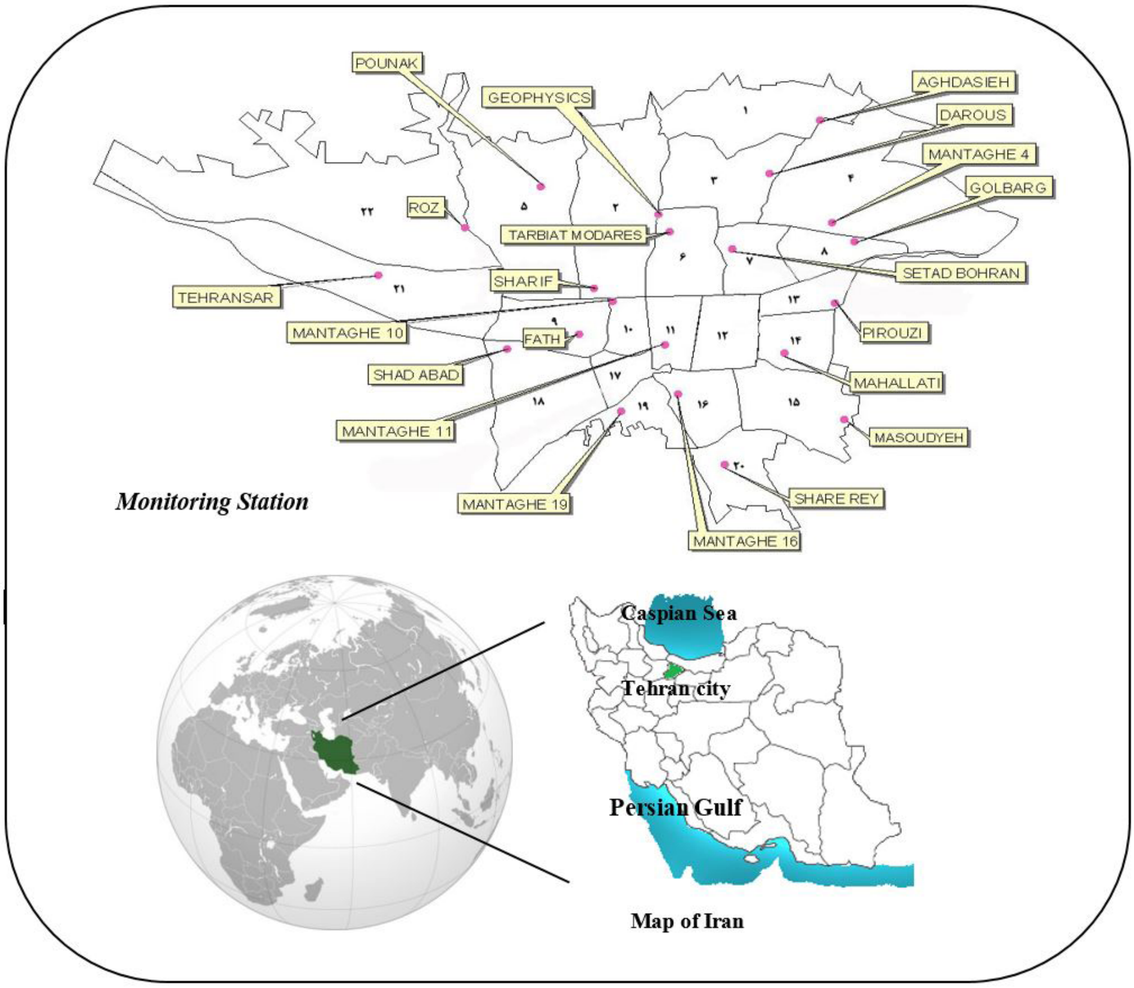

Fig. 1. Location of Iran in the world map, and air quality monitoring stations in the megacity of Tehran

factors including socioeconomic status, maternal nutrition, and education in the recorded cases were the out-of-control variables and considered as limitations of this study.

Air pollution exposure

The air pollutants data (PM, CO, O_3, NO_2, NO_x, NO, and SO_2) was obtained from the Tehran Air Quality Control Company (AQCC). The data of air quality monitoring stations in Tehran were considered as maternal exposure to air pollutants which are shown in Fig. 1. To estimate the maternal exposure during pregnancy, data of stations 5 miles from the mother's residence address recorded on the birth certificate were used [28].

The maternal exposure in each trimester (first, second, and third) was obtained based on the three-month average of PM, CO, SO_2, NO_2, NO_x, NO, and O_3 measured at the monitoring stations considering the birth date recorded on the birth certificates.

Data analysis

Statistical analyses were performed using SPSS. Mann-Whitney test was used to investigate the relationship between exposure to air pollutants in the first, second, and third trimester and incidence of low birth weight and preterm.

Results and discussion

This research was focused on the relationship between maternal exposure to air pollution during pregnancy with LBW and preterm birth. The air pollutants assessed in this research were $PM_{2.5}$, PM_{10}, SO_2, CO, O_3, NO, NO_x and NO_2.

The exposure assessment was based on data of air quality monitoring stations of Tehran city that were closest to the mother's residence. The mean maternal age was 28 years with the range of 15-46 years. About 80% of gestational ages were more than 37 weeks. The mean birth weight of all 1605 newborns included in our analyses was 3117 g.

The relationship between exposure to air pollutants in the first, second, and third trimesters and incidence of low birth weight and preterm birth are presented in Table 1 and Table 2 respectively.

The decision tree modeling for air pollutants and low birth weight and preterm birth are shown in Fig. 2 and Fig. 3.

Based on data analyzed by the Mann-Whitney test, a significant association was found between maternal exposure to $PM_{2.5}$ in the first trimester and incidence of preterm ($p=0.011$) and low birth weight ($p=0.003$) in studied newborns. One study conducted in Northern Bohemia about the impact of particulate matter in fetal development suggested that exposure to particulate matter during pregnancy may affect fetal growth [15]. Also, a close association was observed between maternal exposure to CO in the first and second trimester and LBW ($p=0.002$, $p=0.015$). Exposure to ambient levels of CO may result in the formation of carboxyhemoglobin in the mother, which could result in decreased oxygen delivery to tissues, including the fetus. Inhaled particles, in contrast, have been reported to increase blood viscosity, which may affect placental function, and restrict fetal growth [29].

Since the growth of the fetus is affected by maternal factors, entering air pollutants into the maternal bloodstream via inhalation and absorption may interference with some processes and affect the development of the fetuses [15]. The direct effect can happen when the component crosses the placenta.

Although a significant association was found between maternal exposure to $PM_{2.5}$ and carbon monoxide and preterm and low birth weight in newborns for some trimesters, no statistically significant associations were observed in the case of PM_{10}, SO_2, and O_3. This may be due to the low sample size in our analysis. In the study conducted in the United States, postneonatal mortality rates among infants were observed 3.1 in low exposure, 3.5 in medium exposure, and 3.7 among high exposures to PM_{10} [28]. Their study reported that exposure to particulate matter is associated with the risk of postneonatal mortality.

In our study, NO_2 concentrations in the third trimester have a significant effect on birth weight ($p=0.005$). In the study conducted in Sydney, it was estimated that 1 ppb increases in mean NO2 concentration are related to a reduction of 1 (CI 95%; 0 to 2) to 34 (CI 95%; 24 to 43) grams in birth weight [30].

The results revealed that the higher risk for LBW was related to ambient $PM_{2.5}$ and CO. Since many factors can affect LBW, and the pathogenic mechanisms of the effect of air pollution on low birth weight have not been completely elucidated, the findings should be interpreted with caution and further studies should be conducted on this issue considering the large sample size.

LBW is influenced by many factors, so the relationship between air pollutants and low birth weight is difficult to interpret. In addition, it seems the effect of air pollution on outcomes such as preterm birth and low birth weight is less than the other known factors including cardiovascular and respiratory disease.

However, because of the varying results of the studies in this issue and the limitation of current scientific knowledge, further research is recommended on this issue. Furthermore, as many studies reported air pollution effects on human health, it is recommended that air quality be improved to promote the quality of human life and increase their life expectancy. Therefore, it is necessary to be paid more attention to air quality to reduce its health effect, especially in sensitive groups.

Table 1. Relationship between exposure to air pollutants in the first, second, and third trimester and incidence of low birth weight

Time		Low birth weight				P‡
		No		Yes		
		Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	
First trimester	CO	2.64 ± 0.65	2.73 (2.46 to 3.03)	2.74 ± 0.64	2.83 (2.49 to 3.31)	**.002**
	NO_2	87.62 ± 101.29	45.68 (33.49 to 81.75)	85.66 ± 102.97	37.46 (34.5 to 66.54)	.308
	NO_X	159.13 ± 142.8	97.57 (69.97 to 177.5)	156.29 ± 144.25	90.96 (69.97 to 173.14)	.399
	NO	71.89 ± 53.54	44.11 (30.88 to 116.31)	71 ± 51.75	43.46 (34 to 109.53)	.939
	O_3	18.42 ± 8.91	16.16 (11.6 to 22.2)	18.49 ± 8.24	17.25 (12.17 to 21.25)	.566
	$PM_{2.5}$	40.41 ± 16.85	35.79 (33.1 to 42.01)	36.89 ± 13.84	33.1 (33.1 to 37.48)	**.003**
	PM_{10}	86.75 ± 24.71	85.22 (66.55 to 101.3)	84.28 ± 23.74	83.01 (66.55 to 98.93)	.443
	SO_2	24.32 ± 10.39	23.41 (19.17 to 27.32)	25.21 ± 9.3	24.99 (21.03 to 26.13)	.103
Second trimester	CO	2.45 ± 0.79	2.57 (1.97 to 2.93)	2.55 ± 0.79	2.59 (2.02 to 3.32)	**.015**
	NO_2	79.5 ± 93.03	48.78 (33.79 to 76.51)	80.07 ± 99.17	41.55 (36.67 to 62.44)	.397
	NO_X	143.27 ± 128.69	99.93 (74.88 to 151.24)	146.41 ± 134.52	88.68 (81.56 to 145.61)	.892
	NO	64.2 ± 49.66	47.56 (23.32 to 99.9)	66.09 ± 46.01	48.03 (38.61 to 93.8)	.079
	O_3	19.25 ± 10.34	16.16 (11.19 to 24.8)	18.34 ± 9.34	16.16 (11.33 to 22.84)	.407
	$PM_{2.5}$	43.58 ± 24.21	37.51 (29.47 to 41.93)	39.37 ± 17.65	38.28 (31.03 to 38.28)	.775
	PM_{10}	78.13 ± 26.76	77.8 (57.96 to 97.67)	79.42 ± 27.83	78.93 (63.55 to 96.81)	.467
	SO_2	24.76 ± 8.66	24.15 (19.56 to 27.6)	26.2 ± 8.64	25.7 (23.09 to 26.99)	.043
Third trimester	CO	2.35 ± 0.84	2.27 (1.87 to 2.88)	2.42 ± 0.9	2.36 (1.83 to 3.39)	.190
	NO_2	62.54 ± 66.22	48.66 (34.33 to 68.35)	54.35 ± 57.1	40.53 (36.57 to 52.57)	**.005**
	NO_X	117.85 ± 93.58	93.06 (69.92 to 137.66)	112.21 ± 82.53	88.87 (74.86 to 124.09)	.558
	NO	56.13 ± 45.19	44.11 (20.6 to 79.91)	58.03 ± 39.17	48.34 (32.26 to 69.95)	.053
	O_3	21.79 ± 9.81	19.91 (14.47 to 27.12)	21.93 ± 10.18	18.26 (17.11 to 25.78)	.822
	$PM_{2.5}$	43.27 ± 27.65	33.51 (29.17 to 40.76)	37.89 ± 18.58	36.73 (29.37 to 36.73)	.828
	PM_{10}	71.1 ± 29.8	67.01 (55.8 to 86.85)	71.05 ± 31.16	69.03 (58.32 to 89.45)	.496
	SO_2	25.45 ± 7.46	24.81 (22.77 to 29)	26.15 ± 6.56	26.43 (23.31 to 28.12)	.232

Table 2. Relationship between exposure to air pollutants in the first, second, and third trimester and preterm

Time		Preterm				P‡
		No		Yes		
		Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	
First trimester	CO	2.65 ± 0.64	2.73 (2.46 to 3.03)	2.76 ± 0.62	2.84 (2.49 to 3.31)	.564
	NO_2	87.72 ± 101.42	45.71 (33.48 to 81.93)	86.04 ± 103.34	36.97 (34.18 to 68.9)	.993
	NO_X	159.35 ± 143	97.77 (69.97 to 178.36)	156.92 ± 144.74	91.38 (69.97 to 173.61)	.443
	NO	72.01 ± 53.62	44.11 (30.87 to 116.39)	71.24 ± 51.92	43.46 (34 to 110.25)	.487
	O_3	18.37 ± 8.87	16.09 (11.59 to 22.17)	18.31 ± 8.05	16.97 (12.17 to 21.25)	.613
	$PM_{2.5}$	40.73 ± 16.82	35.87 (33.1 to 42.64)	37.07 ± 13.95	33.1 (33.1 to 37.57)	**.011**
	PM_{10}	86.79 ± 24.73	85.32 (66.53 to 101.45)	84.48 ± 23.83	83.14 (66.23 to 99.03)	.170
	SO_2	24.34 ± 10.42	23.42 (19.16 to 27.34)	25.23 ± 9.34	24.99 (20.96 to 26.13)	.241
Second trimester	CO	2.45 ± 0.79	2.57 (1.97 to 2.93)	2.56 ± 0.79	2.6 (2.1 to 3.34)	.334
	NO_2	79.63 ± 93.24	48.71 (33.74 to 76.71)	80.29 ± 99.6	40.66 (36.67 to 62.44)	.738
	NO_X	143.25 ± 128.95	99.92 (74.86 to 151.08)	146.29 ± 135.12	88.68 (81.56 to 145.2)	.843
	NO	64.06 ± 49.64	47.1 (23.19 to 99.58)	65.73 ± 46.06	48.03 (38.61 to 92.63)	.790
	O_3	19.23 ± 10.34	16.16 (11.12 to 24.67)	18.34 ± 9.38	16.16 (11.14 to 23.09)	.597
	$PM_{2.5}$	43.78 ± 24.31	37.69 (29.48 to 41.93)	39.56 ± 17.78	38.28 (31.73 to 38.28)	.281
	PM_{10}	78.18 ± 26.81	77.85 (57.96 to 97.67)	79.62 ± 27.95	79.69 (64.99 to 96.81)	.458
	SO_2	24.77 ± 8.68	24.22 (19.56 to 27.61)	26.22 ± 8.67	25.7 (23.09 to 27)	**.025**
Third trimester	CO	2.34 ± 0.84	2.27 (1.87 to 2.85)	2.41 ± 0.9	2.35 (1.8 to 3.39)	.594
	NO_2	62.53 ± 66.37	48.55 (34.22 to 68.22)	54.2 ± 57.34	40.53 (36.22 to 52.51)	.295
	NO_X	117.18 ± 93.06	93.06 (69.9 to 137.66)	110.52 ± 80.97	88.87 (73.97 to 121.8)	.478
	NO	55.47 ± 43.89	44.11 (20.49 to 79.33)	56.48 ± 35.81	48.34 (32.21 to 68.75)	.666
	O_3	21.84 ± 9.81	19.92 (14.58 to 27.12)	22.03 ± 10.17	18.26 (17.17 to 25.78)	.736
	$PM_{2.5}$	43.38 ± 27.75	33.49 (29.17 to 40.92)	37.94 ± 18.73	36.73 (29.37 to 36.73)	.940
	PM_{10}	71.14 ± 29.85	66.91 (55.8 to 87.28)	71.07 ± 31.37	69.03 (58.28 to 89.66)	.844
	SO_2	25.47 ± 7.46	24.9 (22.77 to 29.01)	26.17 ± 6.59	26.48 (23.31 to 28.16)	**.028**

‡ Based on Mann-Whitney test

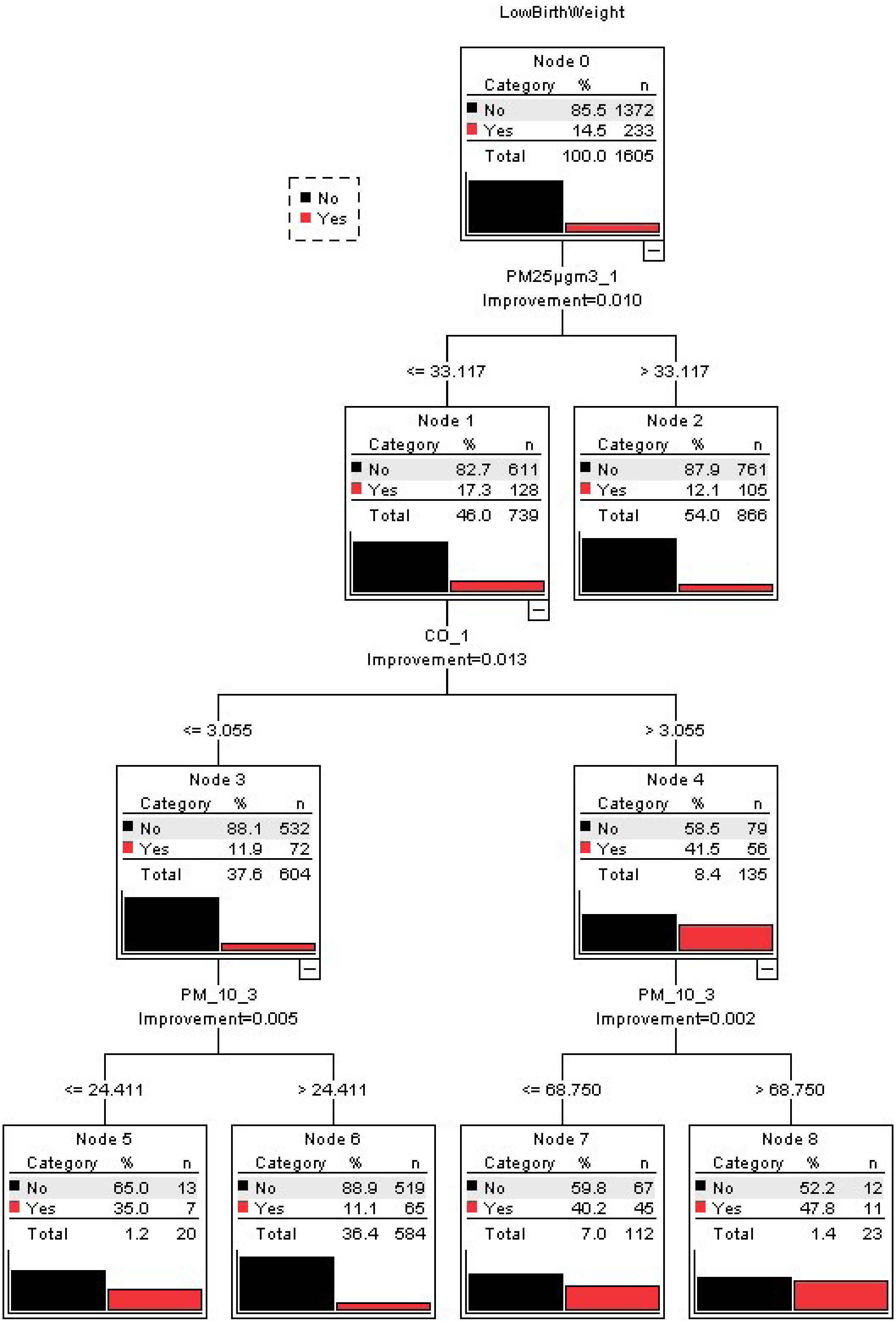

Fig. 2. Decision tree modeling for air pollutants and low birth weight

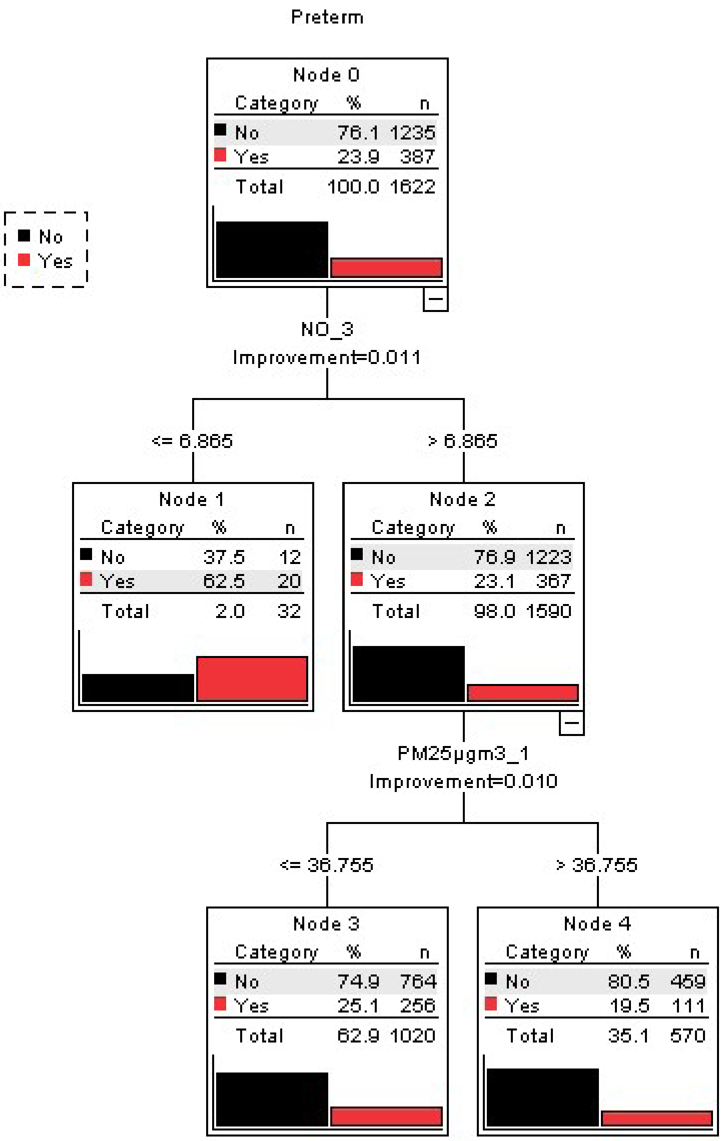

Fig. 3. Decision tree modeling for air pollutants and preterm

Conclusion

This study provides some evidence for the effects of exposure to air pollutants on low birth weight and preterm birth. Although the association was not significant for all studied air pollutants and the results of studies on the effects of air pollutants on the LBW and preterm birth are contradictory, it is still recommended that pregnant women reduce their exposure during pregnancy due to all the known effects of air pollution. Also, health studies can be an effective useful guide for most policymakers who don't have much information and awareness about maternal health effects associated with exposure to air pollution. Hence identifying the health risks of air pollution as a crucial step in the development of successful control strategies can be necessary for the current situation.

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Competing interests

There is no actual or potential conflict of interest among the authors.

Authors' contributions

AHM: Conceptualization, Methodology, supervision; MA; Analysis, data collection, drafting the manuscript, MY: Methodology, Analysis. FAA; Data collection. MR, FY, VP; Data collection, Analysis.

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Ethical considerations

“Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, redundancy, etc) have been completely observed by the authors”.

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