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Original Article

The Effect of PM10 Pollutant Levels on the Postneonatal Mortality Rate: Application of the AirQ+ Model in Istanbul, Türkiye

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Abstract

Background: Air pollution is one of the major environmental risk factors for health. Children are vulnerable to the negative health consequences of air pollution. We aimed to determine the effect of PM10 levels on postneonatal mortality in Istanbul, the most populous city in Türkiye.

Methods: In this cross-sectional study, the relationship between PM10 levels and postneonatal deaths occurring in Istanbul, Türkiye in 2015-2019 was examined. PM10 levels for Istanbul were calculated by taking the average of daily PM10 measurements between 01.01.2015 and 31.12.2019, made available from Istanbul Air Quality Monitoring Stations. Data were analyzed using Microsoft Office Excel 2016 and AIRQ+ 2.2.3 software.

Results: If the PM10 value in Istanbul province had been reduced to 20 μg/m^3, the limit value recommended by the WHO; in 2019; 36(19-61) postneonatal infant deaths could have been prevented; 7.73% (3.98-12.95) of postneonatal infant deaths were attributed to PM10. During this period, the PM10 value in Istanbul was above the limit value recommended by WHO, the European Union and Turkish legislation.

Conclusion: Infant mortality due to air pollution is an important public health problem.

Keywords: PM10; Air pollution; Air Quality; Postneonatal mortality

Introduction

Air pollution is the contamination of the atmosphere by physical, chemical, or biological agents that alter its natural properties. Air pollution is one of the major environmental risk factors for health (1). In 2015, the World Health Assembly recognized air pollution as a risk factor for diseases such as ischemic heart disease, stroke, asthma, chronic obstructive pulmonary disease, and cancer. In 2019, outdoor air pollution was estimated to have caused 4.2 million premature deaths worldwide. Less than 10% of the world's population lives in areas where air quality limit values set by the WHO are not exceeded (2). According to the 2021 WHO, Türkiye ranked 46th among 117 countries and 7th in Europe in terms of pollution levels (3). According to the country profile on health and climate change, 36.698 deaths were reported to have occurred due to air pollution in Türkiye in 2016 (4). While the number of people who lost their lives due to air pollution in Türkiye was 35.314 in 2019, this number is estimated to be 42.067 in 2021(5).

Air quality guidelines and comparison between emerging and developed countries the guidelines

apply in all the WHO regions and regard particulate matter (PM), ozone (O3), nitrogen dioxide (NO2), and sulfur dioxide (SO2) (6). Particulate matter is an important indicator of air pollution. The main components of PM are sulfates, nitrates, sodium chloride, ammonia, mineral dust, black carbon, and water. There is strong evidence of adverse health effects from exposure to this pollutant. In its Air Quality Guidelines updated in 2021, the WHO stated that PM10 causes deaths due to cardiovascular diseases, chronic obstructive pulmonary disease (COPD), acute lower respiratory diseases and lung cancer (2). According to the WHO, a reduction in particulate matter (PM10) pollution from 70 to 20 μg/m^3 can reduce air pollution-related deaths by 15% (7).
Therefore, to protect human health, PM10 exposure should be subjected to continuous and qualified monitoring. In Türkiye, PM10 is the most widely monitored parameter in the National Air Quality Monitoring Network (8). Studies have associated an increase in PM10 levels with an increase in the number of deaths (9). In a meta-analysis, PM10 is associated with increased mortality from all causes, cardiovascular disease, respiratory disease and lung cancer. A meta-analysis showed an increase of 1.04 (95% CI: 1.03, 1.06) for every 10 μg/m^3 increase in PM10 for natural cause mortality (10).
Indoor and outdoor air pollution has become a major threat to children's health. Air pollution is directly related to pneumonia and other respiratory diseases, which are among the causes of death in children under five years of age (11). According to a recent report published by UNICEF, 300 million children in the world live in areas where air pollution is six times or more above international standards (12). Children are vulnerable to the negative health consequences of air pollution. Studies examining the effects of air pollution in the pediatric age group have linked air pollution with infant mortality. In a study evaluating the impact of particulate matter on respiratory diseases and mortality in children and infants in Poland, approximately 5.201 asthma symptoms, 13 hospitalizations for cardiovascular problems and 5 deaths, mostly in the postneonatal period, were attributable to air pollution (13). Woodruff et al. reported overall postneonatal mortality rates of 3.1 among infants with low PM10 exposure, 3.5 among infants with moderate PM10 exposure and 3.7 among infants with high exposure (14).
Mortality measures are indispensable elements of health status analyses, public health studies, program and policy plans and evaluations. The postneonatal period is defined as the period from 28 d to 1 year of age. Postneonatal mortality rates are very valuable for planning and evaluating efforts to protect children's health.
When the main causes of death in the postneonatal period in Türkiye from 2012-2018 are ranked, respiratory system diseases ranked 4th with 4.8%. The United Nations Millennium Development Goals have recognized the reduction of infant and child mortality as one of the priority targets for countries. (15)
The AirQ+ is a software tool for measuring the health impacts of air pollution, developed by the WHO Regional Office for Europe. It can process the following pollutants: PM2.5, PM10, NO2, O3 and black carbon (BC). The calculations can take into account various health outcomes related to mortality and morbidity for both acute and chronic conditions. (16)
We aimed to determine the effect of PM10 levels on postneonatal mortality in Istanbul by AirQ+ software, the most populous city in Türkiye.

Materials and Methods

In this cross-sectional study, the relationship between PM10 levels and postneonatal deaths occurring in Istanbul in 2015-2019 was examined. Air quality data for 2015-2019 were obtained from the National Air Quality Monitoring Network; population and mortality data were obtained from the annual reports of the Turkish Statistical Institute and the Ministry of Health (9, 16, 17). Air pollution parameters in Istanbul are monitored by air quality monitoring stations controlled by the Ministry of Environment, Urbanization and Climate Change or Istanbul Metropolitan Municipality. Between 2015 and 2019, there were 12 air quality measurement stations affiliated with the Marmara Clean Air Center Directorate and 26 air quality measurement stations affiliated with the Istanbul Metropolitan Municipality in Istanbul Province. PM10 levels for Istanbul were calculated by taking the average of daily PM10 measurements between 01.01.2015 and 31.12.2019, made available from Istanbul Air Quality Monitoring Stations.

Data were analyzed using Microsoft Office Excel 2016 and AIRQ+ 2.2.3 software. The effect of PM10 levels on postneonatal mortality in Istanbul was calculated using the AIRQ+ program. The AIRQ+ program allows us to make predictions on the effects of short-term changes in air pollution, the effects of long-term exposures, the attributability of a given health effect to air pollutants, and the possible health effects of future changes in air pollution levels compared to the current scenario. The main scientific evidence on the health effects of ambient air pollution used in the software comes mainly from studies conducted in Western Europe and North America (16,18). The assessment is based on the attributable proportion (AP), defined as the fraction of the health outcome in a given population that can be attributed to exposure to specific atmospheric pollutants. With the distribution of exposure of the population found in the exposure assessment stage, and the relation between exposure and consequence identified, the attributable proportion can be calculated with the formula: (19,20)

AP= £{[RR(c)- 1] * p(c)} [RR(c) *p(c)]

(RR(c) = relative risk for the health outcome in category c of exposure, p(c) = proportion of target population in category c of exposure)

Knowing a certain underlying frequency of the outcome in the population, I, the rate (or number of cases per unit population) attributed to the exposure in the population can be calculated as:

IE = I * AP

For a population of a given size, this can be converted to the estimated number of cases attributed to the exposure.

NE = IE*N

The relative risk (RR) for a given health outcome is defined as the risk of developing an event or a disease relative to exposure and is calculated as: Probability of event with exposure/probability of event without exposure.

For this study, default values of relative risk from meta-analyses in the AirQ+ model were used (21). In this study, the relative risk value for postneonatal mortality 1.04(1.02-1.07). Similar studies from our region have reported that it is possible to use WHO default values (18,22).

In our study, publicly available data from the National Air Quality Monitoring Network and the Turkish Statistical Institute were used. Therefore, ethics committee permission was not obtained. There is no conflict of interest in our study. No financial support was received for the study.

Results

While the postneonatal mortality rate in Istanbul was 3.4 (28 wk or 1,000 g and over) in 2015, it was 2.3 in 2019. While the PM10 level in Istanbul was 51.9 in 2015, it was 40.5 in 2019 (Table 1).

Table 1: Poatneonatal Mortality Rate and PM10 values in Istanbul Province in 2015-2019

Years	*Postneonatal Mortality Rate (per thousand)*	*PM10*
2015	3.4	51.9
2016	2.6	49.0
2017	2.3	55.5
2018	2.2	44.1
2019	2.3	40.5

If the PM10 value in Istanbul province had been reduced to 20 μg/m3, the limit value recommended by WHO; 93(49-154) postneonatal infant deaths could have been prevented in 2015; 11.76% (6.12%-19.41%) of postneonatal infant deaths were attributed to PM10. 64(33-106) postneonatal infant deaths could have been prevented in 2016; 10.75% (5.58%-17.82%) of postneonatal infant deaths were attributed to PM10. 67(35-110) postneonatal infant deaths could have been prevented in 2017; 13.0% (6.79%-21.35%) of postneonatal infant deaths were attributed to PM10. 43(22-72) postneonatal infant deaths could have been prevented in 2018; 9.02% (4.66%-15.05%) of postneonatal infant deaths were attributed to PM10. 36(19-61) postneonatal infant deaths could have been prevented in 2019; 7.73% (3.98%-12.95%) of postneonatal infant deaths were attributed to PM10 (Table 2).

Table 2: Mortality data attributed to air pollution when PM10 value is reduced to 20 μg/m³, the limit value recommended by the World Health Organization

Years	*Variable*	*Central (Lower/Upper)*
2015	Deaths Attributed to Air Pollution %	11.76(6.12-19.41)
	Number of Deaths Attributed to Air Pollution	93(49-154)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.40(0.21-0.66)
2016	Deaths Attributed to Air Pollution %	10.75(5.58-17.82)
	Number of Deaths Attributed to Air Pollution	64(33-106)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.28(0.15-0.46)
2017	Deaths Attributed to Air Pollution %	13.0(6.79-21.35)
	Number of Deaths Attributed to Air Pollution	67(35-110)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.30(0.16-0.49)
2018	Deaths Attributed to Air Pollution %	9.02(4.66-15.05)
	Number of Deaths Attributed to Air Pollution	43(22-72)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.20(0.10-0.33)
2019	Deaths Attributed to Air Pollution %	7.73 (3.98-12.95)
	Number of Deaths Attributed to Air Pollution	36(19-61)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.18 (0.09-0.30)

If the PM10 value in Istanbul had been reduced to 40 μg/m^3, which is the limit value of Türkiye and European Union legislation, 36(19-61) postneonatal infant deaths could have been prevented in 2015; 4.56% (2.33%-7.74%) of postneonatal infant deaths were attributed to PM10. 21(11-35) postneonatal infant deaths could have been prevented in 2016; 3.47% (1.77%-5.91%) of postneonatal infant deaths were attributed to PM10. 29(15-50) postneonatal infant deaths could have been prevented in 2017; 5.7% (2.93%-9.65%) of postneonatal infant deaths were attributed to PM10. 8(4-13) postneonatal infant deaths could have been prevented in 2018; 1.6% (0.81%-

2.74%) of postneonatal infant deaths were attributed to PM10. 1(0-2) postneonatal infant deaths could have been prevented in 2019; 0.20% (0.10%-0.34%) of postneonatal infant deaths were attributed to PM10 (Table 3).

Table 3: Mortality data attributed to air pollution in Istanbul when PM10 value is reduced to 40 μg/m³, which is the limit value of Türkiye and European Union legislation

Years	*Variable*	*Central (Lower/Upper)*
2015	Deaths Attributed to Air Pollution %	4.56(2.33-7.74)
	Number of Deaths Attributed to Air Pollution	36(19-61)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.16(0.08-0.26)
2016	Deaths Attributed to Air Pollution %	3.47(1.77-5.91)
	Number of Deaths Attributed to Air Pollution	21(11-35)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.09(0.05-0.15)
2017	Deaths Attributed to Air Pollution %	5.7(2.93-9.65)
	Number of Deaths Attributed to Air Pollution	29(15-50)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.13(0.07-0.22)
2018	Deaths Attributed to Air Pollution %	1.6(0.81-2.74)
	Number of Deaths Attributed to Air Pollution	8(4-13)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.04(0.02-0.06)
2019	Deaths Attributed to Air Pollution %	0.20(0.10-0.34)
	Number of Deaths Attributed to Air Pollution	1(0-2)
	Mortality Rate Attributed to Air Pollution (per 1.000)	0.00 (0.00-0.01)

Discussion

In this study, we evaluated the effect of PM10 air pollutant exposure on postneonatal mortality using AIRQ+ software. The AirQ software model can be used as a useful and easy tool in the decision making process (23,24). In our study, although lower PM10 values were measured in Istanbul in 2019 compared to 2015, the current values were found to be above WHO, Türkiye and EU standards. The PM10 level of 51.9 μg/m^3 in 2015 decreased to 40.5 μg/m^3 in 2019, which shows that deaths due to air pollution can be significantly prevented. In the years evaluated within the scope of the study, the highest particulate matter pollution was measured as 55.5 μg/m^3 in 2017, and the mortality rates attributed to air pollution were the highest in this year (13.0 (6.79-21.35); 5.7 (2.93-9.65)). Some studies showing that air pollution causes deaths in the pediatric age group, especially due to respiratory failure. Cambra et al, a 5 μg/m^3 reduction in the annual mean value of PM10 was associated with a reduction of 23 postneonatal deaths per year (5 from respiratory causes (1.4/100.000 children)). Overall, 56 postneonatal deaths (13 from respiratory causes (4.7/100.000 children), including 13 from respiratory causes (4.7/100.000 children)) could be prevented (to be controlled) by reducing

PM10 values to the limit value of 20 μg/m^3 (18). According to a report by the Republic of Türkiye Ministry of Health, respiratory system diseases accounted for 4.8% and respiratory tract infections accounted for 5.3% of the causes of death in the postneonatal period according to the 2012-2018 report (17). The specific causes of postneonatal deaths in Istanbul are not known, but our study showed that 37 deaths could have been prevented in 2019 if PM10 values reached the limit value of 20 μg/m^3.

Reducing the annual mean value of PM10 to 40 μg/m^3 in six Central-Eastern European cities (with annual mean PM10 values between 22.0 and 62.0 μg/m^3) would prevent approximately 7 postneonatal deaths each year in Kraków and Bucharest, while reducing PM10 to 20 μg/m^3 would prevent a total of 21 postneonatal deaths in 6 cities (25). In Istanbul, PM10 values varied between 40.5 and 55.5 μg/m^3 during our study. Overall, 29 deaths could be prevented if the PM10 level could reach the WHO limit value of 40 μg/m^3 in 2017, when the highest pollution was measured. In Taiwan, 4.0% of the risk of postneonatal death was attributed to an increase in PM10 (26). In the USA, for every 10 μg/m^3 increase in PM10, the probability of respiratory-related postneonatal death increased by 16%. [OR = 1.16; 95% confidence interval (CI), 1.06-1.27] (27). In our study, the mortality rate attributed to air pollution was 13.0 (6.79-21.35) when the PM10 level was 55.5 in 2017, while the mortality rate attributed to air pollution was 9.02 (4.66-15.05) when the PM10 level was 44.1 in 2018. A decrease of approximately 10 μg/m^3 in PM10 levels in successive years was found to reduce mortality rates. Kaiser et al. found that the all-cause postneonatal mortality rate increased by 4% (95% confidence interval [CI] 2-7%) for every 10 μg/m^3 increase in PM10 (28). In our study, the mortality rate attributed to air pollution was 11.76% (6.12%-19.41%) when the PM10 level was 51.9 in 2015, while the mortality rate attributed to air pollution was 7.73% (3.98%-12.95%) when the PM10 level was 40.5 in 2019.

The most important strength of our study is that it was conducted in Istanbul, the most populous city in our country, where industrialization, traffic and construction are the most intense; therefore, our results may constitute a profile for our country. However, the fact that we could not access cause-specific postneonatal mortality data can be considered a limitation. The main reason why the study was limited to the years 2015-2019 is the consideration of the COVID-19 period (due to restrictions, changes in air pollution parameters, changes in the number of deaths, etc.) and limited data sharing by the Turkish Statistical Institute. An important limitation of the study is the comparison of relative risk estimates from studies in different populations with those under investigation and the assumption that concentrations measured at specific locations in the city represent average exposure. However, the studies conducted in our region show that the AIRQ software provides an effective and easy tool for decision-making in determining exposure. (23,29) In addition, the number and distribution of measurement stations in our city facilitates generalizability.

Conclusion

We showed the association of air pollution levels with postneonatal mortality for five years. Postneonatal mortality can be prevented when air pollution is reduced. The PM10 limit value in Istanbul, Türkiye's most populous city, is above the limit value recommended by the WHO, the European Union and Turkish legislation. Infant mortality due to air pollution is an important public health problem. This result should be considered in future public health risk assessment and management. Monitoring air pollution parameters and reducing them below the limit values is important for public health. The AirQ software model can be used as a useful and easy tool for decision-making regarding the effects of air pollution on humans.

Journalism Ethics 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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Conflict of Interest

The authors declare no conflict of interest.

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