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The Effect of Particulate Air Pollution on Infant Mortality in the Short Term: The Case of Ankara Province in 2018-2020

Partiküler Hava Kirliliğinin Bebek Ölümlerine Kısa Dönemdeki Etkisi: 2018-2020 Yılları Ankara İli Örneği

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Abstract

Background: Today, nine out of 10 people on a global scale live in an air pollution environment above the limit values determined. It is predicted that particulate air pollution is a risk factor for 5.3% of deaths under the age of one in Türkiye. In order to examine the causes of infant deaths and take necessary precautions, it is important to investigate air pollution and the possibilities of infant death due to.

Aims: This study was carried out to examine the relationship between Particulate Matter (PM) 2.5 and (PM)10 levels observed in Ankara between the years 2018-2020 and infant deaths that occurred at that time.

Methods: To examine the relationship poisson regression model, in which the terms formed by the flexible cubic spline function, were mainly used. The effect of each 10 µg/m3 increase in PM2.5 and PM10 on infant mortality, taking into account lags of up to seven days by adjusting for seasonal trends and air temperature effects, was determined by relative risk (RR) and 95% confidence intervals (CI) analyzed by calculation.

Results: In the evaluated period, 1295 infant deaths occurred in 754 of 1096 days. The three-year average of the daily average PM2.5 and PM10 levels detected in Ankara is above the limit values.

Conclusion: The effect of particulate air pollution on infant mortality in the first week was not detected, this relationship may become detectable when different variables such as possible effect modifiers are included in the models applied. The subject should also be examined under such different conditions.

Keywords: Environmental epidemiology, Time series, Air pollution, Infant mortality

Özet

Genel bilgiler: Günümüzde küresel ölçekte her 10 kişiden dokuzu hava kirliliği sınır değerlerin üstünde olan yerlerde yaşamaktadır. Türkiye'de bir yaş altı ölümlerin %5,3'ünün risk faktörünün partiküler hava kirliliği olduğu öngörülmektedir. Bebek ölümlerinin nedenlerinin incelenerek gerekli önlemlerin alınabilmesi açısından hava kirliliği ve kirliliğe bağlı erken ölüm olasılıklarının araştırılması önemlidir.

Amaç : Bu çalışma, Ankara'da 2018-2020 yılları arasında gözlenen Partikül Madde (PM) 2.5 ve (PM)10 düzeyleri ile o dönemde meydana gelen bebek ölümleri arasındaki ilişkiyi incelemek amacıyla yapılmıştır.

Yöntem: Partiküler hava kirliliğinin bebek ölümleriyle olan ilişkisinin irdelenmesinde temel olarak esnek kübik spline fonksiyonuyla oluşturulan Poisson regresyon modeli kullanılmıştır. Mevsimsel trendler ve hava sıcaklığı etkisi arındırılarak yedi güne kadar olan etki gecikmeleri (lag) göz önüne alınıp her 10 µg/m3'lük PM2.5 ve PM10 artışının bebek ölümleri üzerine olan etkisi rölatif risk (RR) ve %95 güven aralıkları (GA) hesaplanarak incelenmiştir.

Sonuçlar: Ankara'da saptanan günlük ortalama PM2.5 ve PM10 düzeyinin üç yıllık ortalaması limit değerlerin üzerindedir ve değerlendirilen zaman diliminde, 1096 günün 754'ünde 1295 bebek ölümü gerçekleşmiştir.

Yapılan hesaplamalarda hem PM2.5 hem de PM10'un yüksek değerlerine maruziyet günü ve sonraki ilk üç günde ölüm riskinde değişiklik yokken sonraki günlerde ölüm riskinin anlamlı olarak düştüğü ve yedinci günde bu farkın ortadan kalktığı gözlemlenmiştir. Sonuçta PM2.5 ve PM10 ile yapılan hesaplamalar, partiküler hava kirliliğinin ilk haftada bebek ölümleri üzerine etkisi gösterilememiştir.

Tartışma: Partiküler hava kirliliğinin ilk haftada bebek ölümleri üzerine etkisi saptanmamasına rağmen uygulanan modellere olası etki düzenleyiciler gibi farklı değişkenler dahil edildiğinde bu ilişki saptanır hale gelebilir. Konunun bu gibi farklı koşullarla da incelenmesi gerekmektedir.

Anahtar kelimeler: Çevre epidemiyolojisi, Zaman serisi, Hava kirliliği, Bebek ölümü

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Background

Air pollution is the pollution of the indoor or outdoor environment by any chemical, physical or biological agent that changes the natural properties of the atmosphere.[1] While the main cause of air pollution is fossil fuels, the main air pollutants are particulate matter (PM_{10}, $PM_{2.5}$), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO).[2]

While particulate matter, which is one of the air pollutants, was declared carcinogenic by the World Health Organization (WHO) in 2013, the maximum annual limit values were determined as 15 μg/m3 for PM_{10} and 5 μg/m3 for $PM_{2.5}$.[2] Worldwide, nine out of 10 people live above the limit values determined by WHO, in other words, they breathe polluted air.[1]

The air pollution parameters of only two provinces (Bitlis and Hakkari) in Türkiye in 2020 were below the guide values recommended by WHO. Again in 2020, Turkey was the 46th most dirty aired country in the world and the 9th country in Europe. Based on the Sites Station in Ankara, it has been shown that air pollution problems are over 220 days of the year's guide values, and sometimes the pollution has reached dimensions that can seriously affect health by increasing the guide values up to four times.[3,4]

It is well documented that in cases such as inversion events where air pollution is very intense, it can cause major public health problems in a very short time, also less intense air pollution threatens public health.[5] Outdoor and indoor air pollution plays an important role as a source of morbidity and mortality, especially by causing respiratory diseases. According to WHO data, a total of seven million people die every year in the world due to diseases caused by air pollution.[1]

Air pollution is recognized as the biggest environmental health threat. In the ranking of causes of death in the world, outdoor air pollution ranks sixth, and indoor air pollution ranks eighth.[6] Biological mechanisms such as increasing the release of cytokines by particulate matter, activation of the coagulation cascade, decreasing plaque stability, and causing cardiac autonomic dysfunction have been demonstrated in the association of air pollution with deaths.[7,8] The elderly, infants, and people with chronic diseases are most affected by the death and serious morbidity effects resulting from short-term acute high exposures.[7]

Air pollution is a serious risk factor for mortality and disease burden not only for adults but also for infants. In general, air pollution can cause health problems such as respiratory system diseases such as asthma, chronic obstructive pulmonary disease (COPD), bronchitis, pneumonia,[9] Type 1 diabetes,[10] autism,[11] mental retardation[12] in infants, while short-term exposure to pollution can also cause low birth weight and its effect on sudden infant death syndrome[13] have been demonstrated.

In Figure 1, infant deaths (under the age of one) and the burden of disease are shown in Türkiye and in the world, where outdoor particulate air pollution is a risk factor over the years.[14]

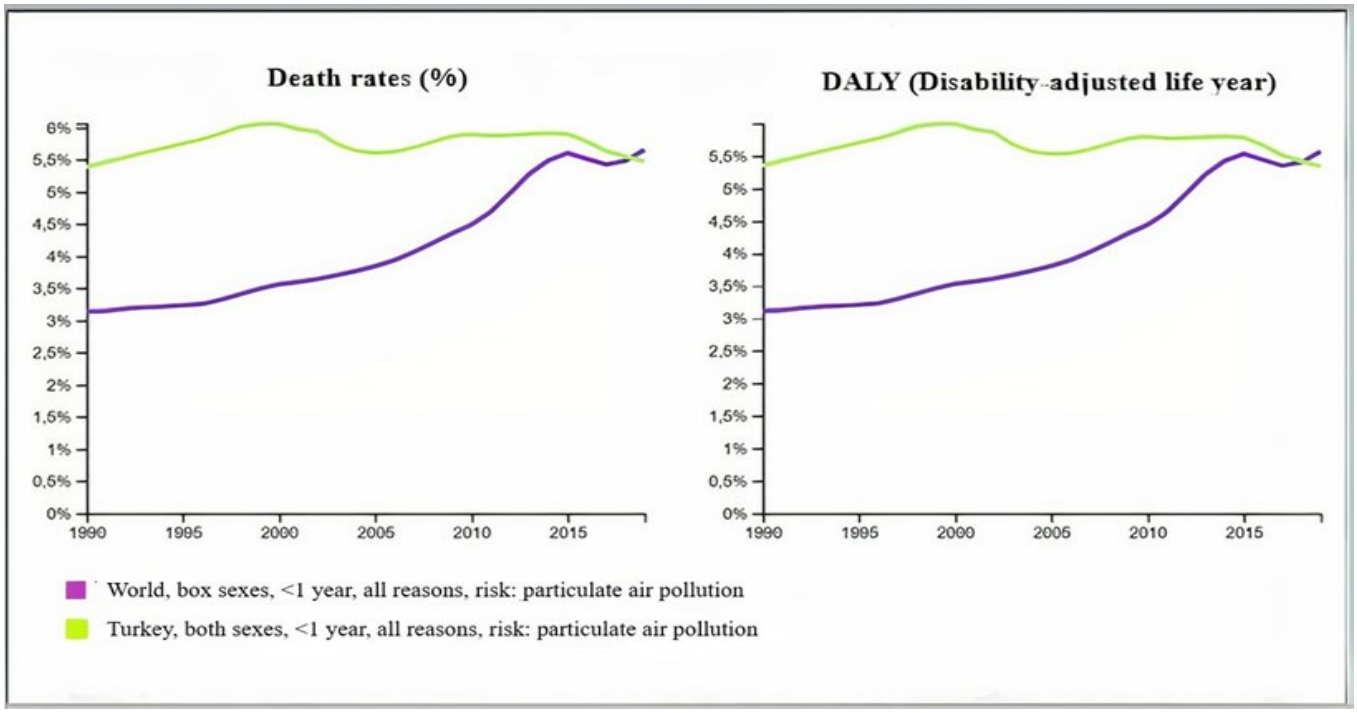

Figure 1. *The Share of Particular Air Pollution as a Risk Factor in Infant Deaths and Disease Burden in Turkey and in the World (Reference, Global Health Data Exchange. GBD Results Tool | GHDx [Internet]. [cited 2021 Nov 5]. Available from: http://ghdx.healthdata.org/gbd-results-tool).*

In studies of the relationship between particulate air pollution and infant mortality, there are studies reflecting that the risk of death increases in the first days after exposure to pollution, and there are studies in the literature that do not demonstrate such a relationship. In some cases, the risk of death rising in the early days after exposure to pollutants at high doses may bring a decrease in death frequencies in the following days. This is called "Harvesting". The possible explanation for this effect is that the deaths that may occur after a certain period occurs in patients who are critical due to exposure.[15]

Material-Method

In the context of health protection in Türkiye, the causes of infant deaths should be examined and necessary measures should be taken. Considering the air pollution in Ankara province and the possibility of infant deaths due to pollution, it is important to investigate this relationship. The relationship between air pollution data and deaths pollution was made at the city scale, similar to the studies using the APHEA protocol (Agency for Public Health Education Accreditation), but the acceptable proportion of lost data per station, which was 25% in the protocol, increased to 33%[16] and stations with complete data for two-thirds of the entire study time were included in the study. From the eight stations operating in Ankara since 2018, the PM_{10} data of seven of them meeting these criteria and the $PM_{2.5}$ of four of them were used. Also based on the literature, the average measurements of the stations were calculated and the pollution data of the relevant day had been obtained. [17–19] There is no loss in PM_{10} data calculated by averaging, while there is a 0.9% loss in $PM_{2.5}$. Missing data were completed by averaging the two measurement days closest to the missing day. With the use of the numbers and percentages of infant mortality data, basic characteristics of infants who died were defined, infant mortality was considered the dependent variable and midday air temperature was considered confounding, and the relationship between particulate air pollution values and infant mortality was investigated. RStudio (RStudio Team (2021). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com) was used in the calculations.

In the relationship of particulate air pollution with infant mortality, the Poisson regression model was used, in which the terms formed by the flexible cubic spline function were included. For this purpose, firstly, a spline curve using a total of 20 nodes was created. In the established Poisson regression model, the relationship between particulate air pollution and infant mortality was calculated using this curve, removing the effects of seasonal trends and then air temperature, and taking into account lags of up to seven days. The effect of each 10 μg/m3 increase in $PM_{2.5}$ and PM_{10} on infant mortality was investigated by calculating the relative risk (RR) and 95% confidence intervals (CI).

Results

Between 2018 and 2020, 1295 infant deaths occurred in Ankara. Descriptive data on infant deaths are presented in Table 1. The data contains some missings. Since the main purpose of the study was to examine the relation between the number of infant deaths per day and particulate air pollution, existing missing data such as gender and birth weight were not taken into account in the regression analysis. Among the causes of infant deaths, prematurity is the first in rank and constitutes more than half of all deaths. Heart diseases are in second place, followed by metabolic and syndromic diseases (Table 2).

Table 1. *General characteristics of infant death cases in Ankara Province in 2018-2020.*

	n	%
Gender (n=1292)		
Male	710	55
Female	582	45
Birth weight (gram) (n=1290)		
>2500	354	27.4
≤2500	936	72.6
Pregnancy Week (n=1292)		
≥37	361	27.9
<37	931	72.1
Mother's Age (years) (n=1285)		
<35	1115	86.8
≥35	170	13.2
Infant's Age (months) (n=1292)		
1-2	965	74.7
3-12	327	25.3

Table 2. *Causes of Infant Mortality Ankara Province in 2018-2020.*

Cause of mortality	**Number**	**%**
Prematurity	759	58.6
Heart diseases (Congestive heart failure, Pulmonary Hypertension, etc.)	201	15.5
Metabolic and syndromic diseases	137	10.6
Respiratory diseases (Respiratory Distress Syndrome, Pneumonia, etc.)	69	5.3
Sudden Infant Death Syndrome	46	3.6
Asphyxia and deaths due to aspiration	37	2.9
Infectious diseases (sepsis etc.)	27	2.1
Other diseases	19	1.4
Total	**1295**	**100**

In the evaluated period, 1295 infant deaths occurred in 754 of 1096 days, while the highest number of infant deaths in one day was seven. The mean daily $PM_{2.5}$ levels detected in Ankara are between 2.95-110.68 µg/m3 and the three-year average is 18.15±11.60 µg/m3. PM_{10} levels are between 12.77-314.76 µg/m3, with a three-year average of 53.73±32.88 µg/m3. As expected, peaks in particle levels were observed in autumn and winter (Figure 2,3).

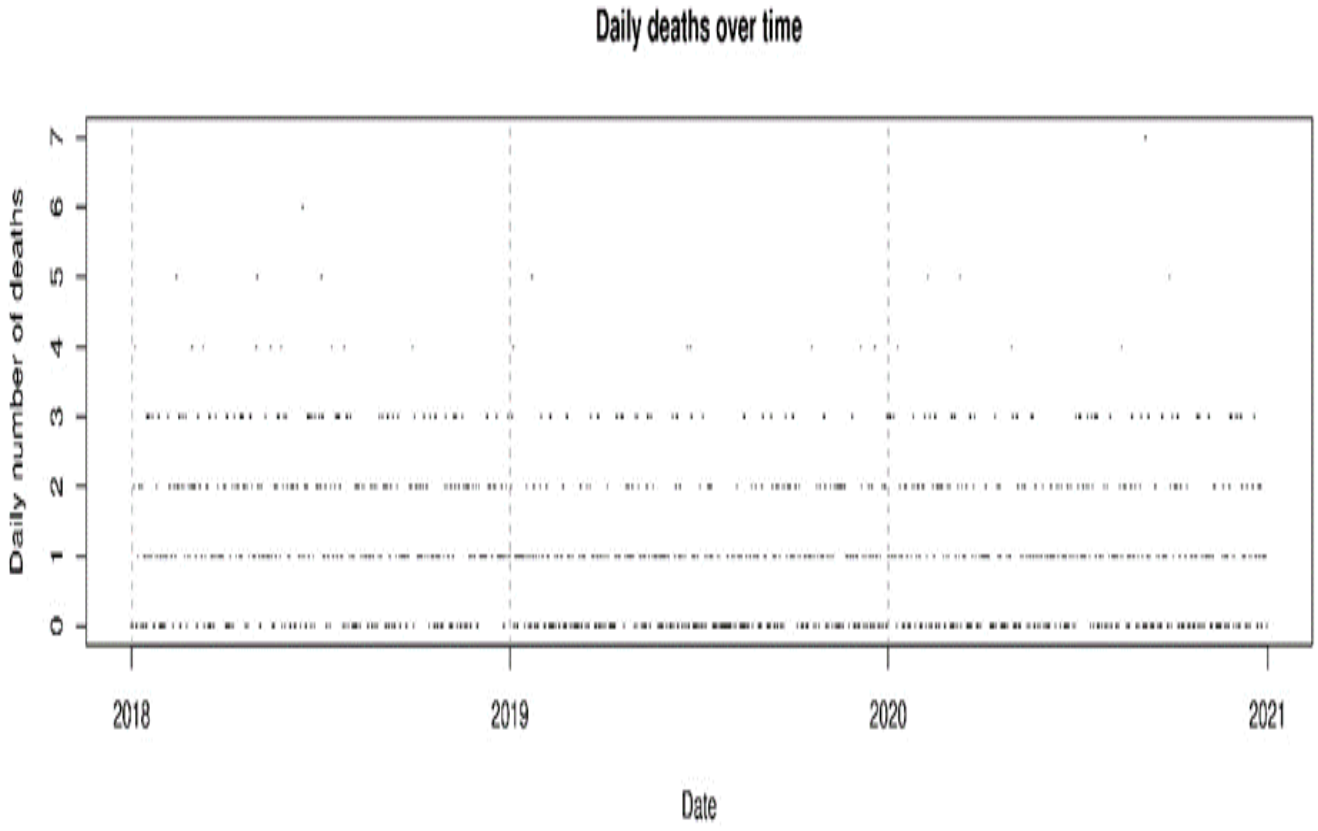

Figure 2. *Number of deaths and the distribution of PM_{10} ve $PM_{2.5}$ levels by the years, Ankara Province in 2018 2020.*

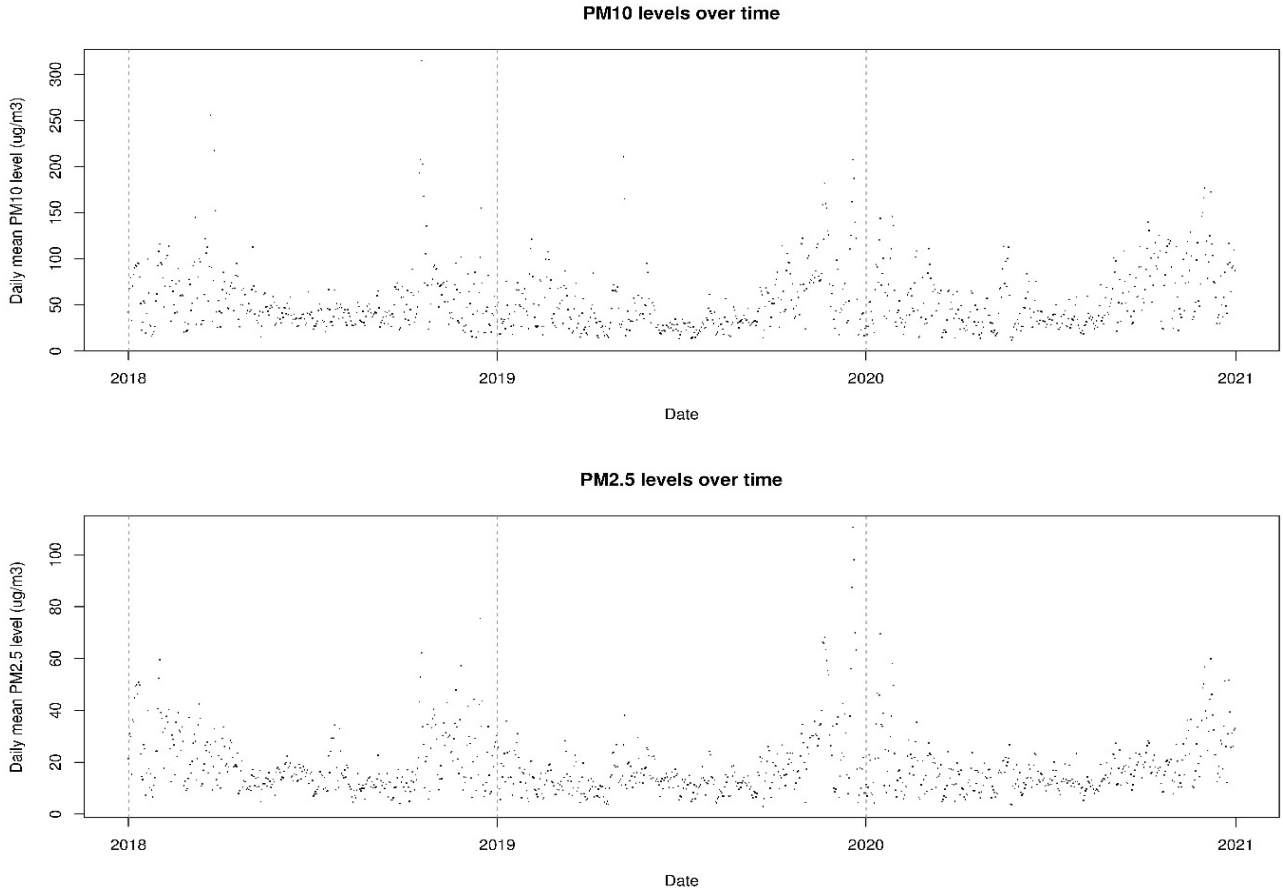

Figure 3. *Change of PM_{10} and $PM_{2.5}$ level over time.*

In order to examine the relationship between particulate air pollution and infant mortality, the Poisson regression model, in which the terms formed by the flexible cubic spline function were included, was used (Figure 4).

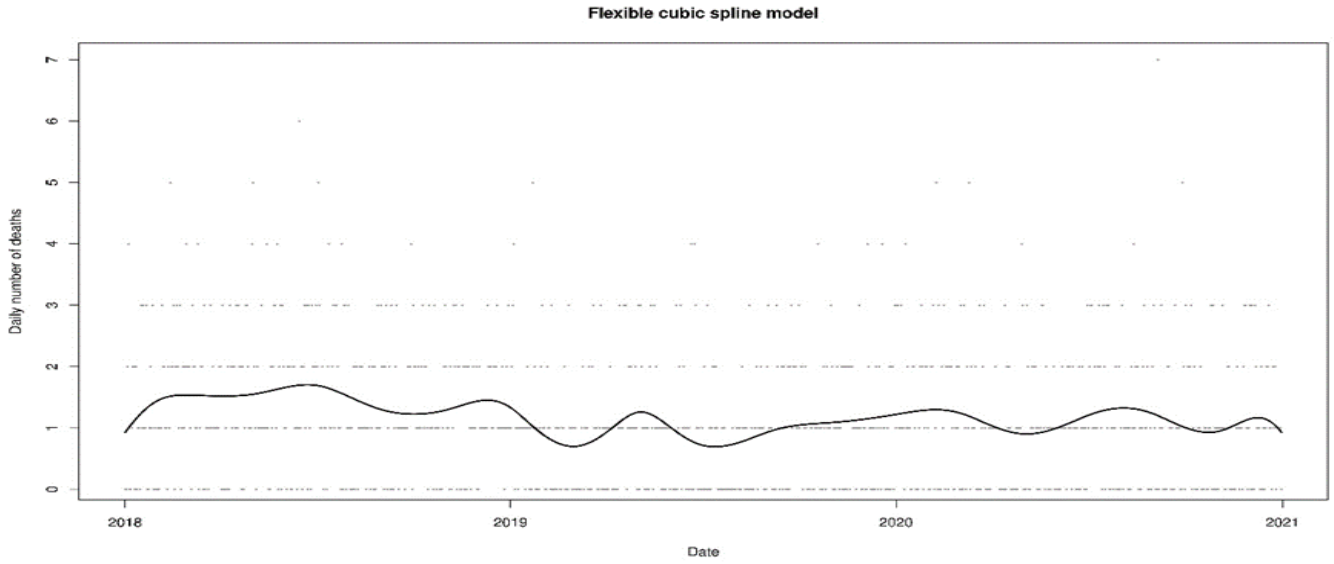

Figure 4. *Representation of the relationship between infant deaths and particulate air pollution with a flexible cubic spline model, Ankara Province in 2018-2020.*

Calculations reflected that there was no change in the risk of death on the day of exposure to high values of both $PM_{2.5}$ and PM_{10} and in the first three days after, for $PM_{2.5}$ on days four, five and six reflecting a significantly lower risk of death. This difference also disappeared on the last day (Day 7^{th}) examined (Table 3) (Figure 5).

Table 3. *Generalize Linear Model, about the effect of PM_{10} and $PM_{2.5}$ on infant death. (per 10 µg/m3 particulate pollutants increase).*

	lag	RR (95% Cl)
PM_{10} (µg/m^3)	0	0.991 (0.970-1.012)
	1	0.993 (0.972-1.014)
	2	0.994 (0.973-1.015)
	3	0.997 (0.976-1.018)
	4	0.970 (0.948-0.992)
	5	0.968 (0.947-0.990)
	6	0.974 (0.953-0.996)
	7	1.000 (0.979-1.020)
$PM_{2.5}$ (µg/m^3)	0	0.962 (0.906-1.021)
	1	1.006 (0.949-1.067)
	2	0.993 (0.936-1.052)
	3	0.961 (0.905-1.021)
	4	0.945 (0.889-1.004)
	5	0.916 (0.861-0.975)
	6	0.935 (0.879-0.994)
	7	1.010 (0.953-1.070)

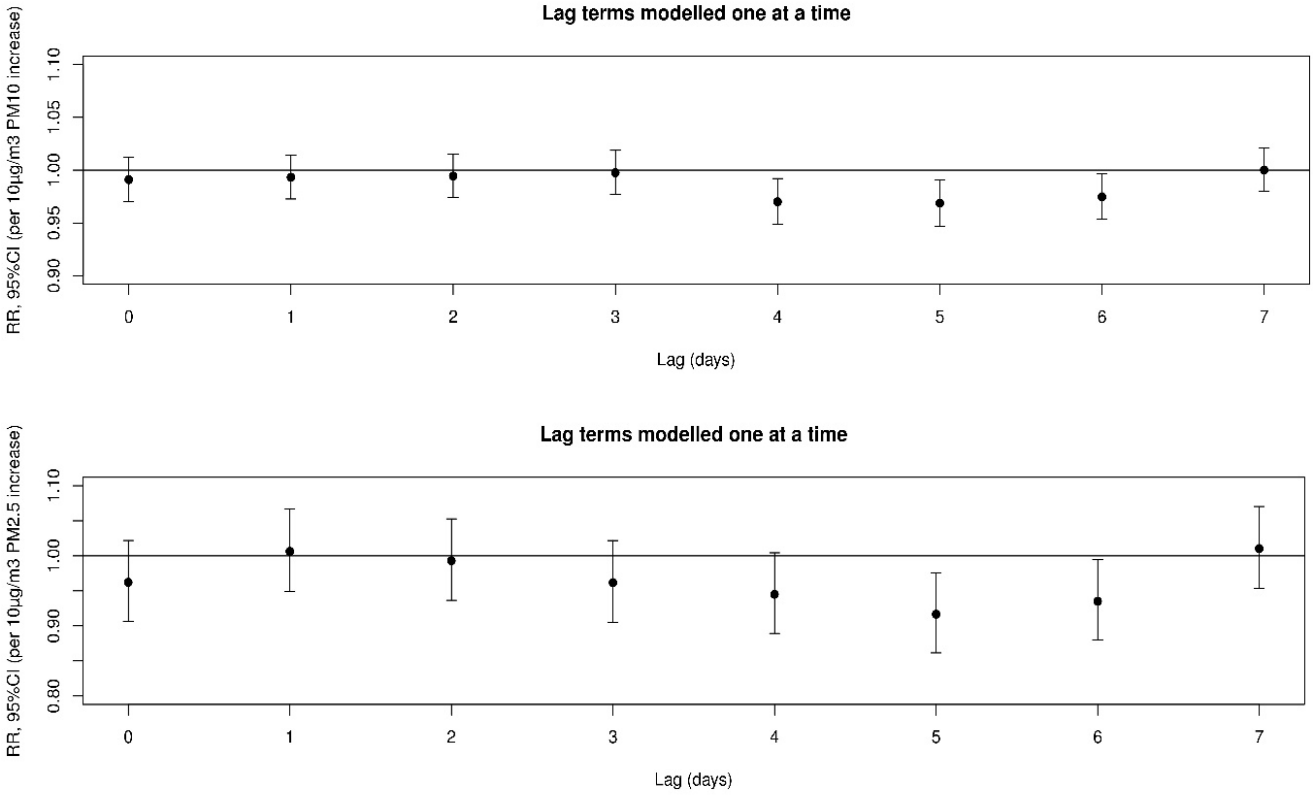

Figure 5. *Lag terms modeled one at a time for PM_{10} and $PM_{2.5}$*

Discussion

Considering the possibility that air pollution-related infant deaths will develop a few days later rather than the day when the pollution is intense, delays of up to one week are taken into account, and neither PM_{10} nor $PM_{2.5}$ levels are risk factors for infant mortality in the results, in which long-term trends and air temperature are excluded not shown. These findings may be related to the fact that PM measurements do not represent actual exposure or that errors due to measurements and calculations are insufficient to show the existing relationship. In addition, considering that 94.7% of these deaths occur in hospitals, the short-term effect of outdoor air pollution may have decreased in the hospital environment where the last days of life are spent.

Harvesting is a phenomenon that mentions the decline in infant deaths in 4-6. days, after the rise in the first days of air pollution. Accordingly, deaths that are expected to occur after a certain period of exposure to the health risk may shift to the early stages (first days) of exposure, so days when the risk of death is relatively reduced after a certain period of exposure can be seen. However, in our study, no increase in deaths was observed in the first days of exposure to high-dose particulate pollution, in this case, it is also not correct to attribute the decrease in 4-6 days to the "harvesting" effect. There is no biological mechanism to explain the fact that death risk is not seen in the first days but in 4-6 days and this change is in the form of a decrease. As a result, neither $PM_{2.5}$ nor PM_{10} calculations showed the effect of particulate air pollution on infant mortality in the first week.

When very high levels of pollution were observed in London in the 1950s, sharp increases in infant mortality occurred.[20] Similar to this one, in a study examining 2798 infant deaths between 1993-95 in Mexico City, which is using time series, it was observed that infant deaths were strongly related to the mean $PM_{2.5}$ concentration, especially during the 3-5 days before death.[20] Again, in a different study in Mexico City (including 1997-2005) and in a study that included 22288 infant deaths between 1990 and 2000 in 10 big cities in England, no significant relationship was observed between infant mortality and PM_{10} and $PM_{2.5}$.[17,19] In a study conducted in Seoul in 1995 and 1999 using Poisson regression, PM_{10} was found to be a risk factor for postneonatal deaths.[21]

In the literature, the relationship between air pollution and infant mortality has also been examined in case-crossover studies, apart from time series. While studies conducted in Taipei, Kaohsiung, Mexico city, and Seoul did not find a relationship between air pollution and infant deaths,[17,18,22,23] studies conducted in Flanders, Tokyo, Belgium, are cross-case control studies which found a relationship between particulate air pollution and infant deaths.[24,25] Differently, in a cohort study conducted in the USA, no relationship was found between particulate air pollution and infant mortality due to all causes.[26]

Some of the studies that found a relationship between infant mortality and air pollution were carried out over a longer period than this study, and some focused on infant deaths mainly. It can be thought that the relationship explored in studies conducted in the past, where the unmet health needs were higher, and studies with longer duration and in which more deaths were included in the analysis, would be more easily demonstrated.[27] The inclusion of more stations in the study, as in the study carried out in Seoul, may have provided a more accurate measurement of exposure to air pollution, thereby demonstrating the effect more clearly.[21]

This study, which investigated the relationship between infant deaths and particulate air pollution, has limitations. The first of these may be the inability of air pollution measurements to represent exposure to particulate air pollution, which is considered a risk factor. There may be errors related to measurement and data, or missing data may have led to the failure to detect a possible relationship. Although it is based on the measurements of seven stations, the acceptable proportion of lost data per station from 25% in the APHEA protocol has been increased to 33% to keep the number of stations included high. Thus, the number of stations that can be included has been increased from 2 to 7, despite an additional 8% loss in lost data. Instead of associating the station measurements with the deaths in the surrounding geography, in this study, it is assumed that air pollution changes in the geography that includes the whole of Ankara Province. Apart from these, open-air particulate air pollution may not cause deaths with a short-term effect. In parallel with the decrease in unmet health needs over the years, babies with impaired general health can be hospitalized more frequently nowadays,[28] thus these babies may be exposed to outdoor air pollution less in today's conditions.

Although some studies are showing the relationship between air pollution and death due to certain causes, in this study, the relationship of particulate air pollution with all-cause infant deaths was investigated, regardless of the diseases reported as the last cause of death. The lack of a relationship in this study is not intended to investigate the role of air pollution in infant deaths due to different reasons, and it is not possible to make inferences on this issue.

Limitations of the study

The limitations of this study which investigates the relationship between infant mortality and particulate air pollution can be summarized as follows. The first of these may be the inability of air pollution measurements to represent exposure to particulate air pollution, which is considered a risk factor. There may be errors in the measurements and data, as well as missing data that may have caused to be unable to detect a possible relationship. Although it is based on the measurements of 7 stations, the acceptable lost data rate per station from 25% in the APHEA protocol has been increased to 33% to keep the number of stations included high. So, the number of stations that can be included has been increased from 2 to 7, despite an additional 8% loss in data. Instead of associating the station measurements with the deaths in the surrounding areas of the stations, in this study, it is assumed that air pollution changes in the whole of Ankara.

Apart from these, open-air particulate air pollution may not cause deaths with a short-term effect today. In parallel with the decrease in unmet health needs over the years, infants with impaired general health may be hospitalized more frequently nowadays, therefore they may be less exposed to outdoor air pollution in today's conditions. Although some studies are showing the relationship between air pollution and deaths due to certain causes, in this study, the relationship of particulate air pollution with all-cause infant mortality was investigated, regardless of the diseases reported as the last cause of death. This study is not intended to investigate the role of air pollution in infant deaths due to different reasons, and it is not possible to make inferences on this issue. Further research is needed that covers longer time spans.

Conclusion

No significant relationship was found between particulate air pollution and infant deaths. The reason why no statistically significant results were obtained from the calculations made in the investigation of the considered relationship may be due to many different reasons such as study design, data completeness and accuracy, data processing preferences, and analysis selection. Although it is more difficult to detect compared to previous studies, the lack of significant results in this study does not mean that the relationship does not exist. Research on the effect of particulate air pollution on infant deaths in the short term needs to be repeated in different designs, in different models that include different variables such as possible effect modifiers, and in different geographies. Studies in this direction can provide guiding results in terms of infant health on a national scale.

Added value of this study

There are many valuable studies carried out nationwide related to air pollution issues.[4] But to our knowledge, with this study we present data for the first time for trends of infant mortality and particulate air pollution in our Country. Though as we mentioned above the study has limitations (data is limited for the Capital City Ankara and limited for the years 2018-2020) the study perspective may shed light on different studies.

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Conflicts of Interest

The authors declare that they have no competing interests.

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