



The effects of desert dust storms, air pollution, and temperature on morbidity due to spontaneous abortions and toxemia of pregnancy: 5-year analysis

Mustafa Bogan¹ · Behcet Al² · Seval Kul³ · Suat Zengin⁴ · Murat Oktay⁵ · Mustafa Sabak⁶ · Hasan Gümüőboęa⁷ · Hasan Bayram⁸

Received: 18 February 2019 / Revised: 7 March 2021 / Accepted: 2 April 2021
© ISB 2021

Abstract

Epidemiological studies have suggested an association between particulate air pollution, increased temperatures, and morbidity related to pregnancy outcomes. However, the roles of desert dust storms and climatological factors have not been fully addressed. The objectives of the present study were to investigate the association between desert dust storms, particulate matter with a diameter $\leq 10 \mu\text{m}$ (PM_{10}), daily temperatures, and toxemia of pregnancy and spontaneous abortion in Gaziantep, South East Turkey. The study was conducted retrospectively at emergency department of two hospitals in Gaziantep city. Data from January 1, 2009, to March 31, 2014, were collected. Patients, who were diagnosed with toxemia of pregnancy and spontaneous abortion by radiological imaging modalities, were included in the study. Daily temperature ranges, mean temperature values, humidity, pressure, wind speed, daily PM_{10} levels, and records of dust storms were collected. A generalized additive regression model was designed to assess variable effects on toxemia of pregnancy and spontaneous abortion, while adjusting for possible confounding factors. Our findings demonstrated that presence of dust storms was positively associated with the toxemia of pregnancy both in outpatient admissions ($\text{OR}=1.543$ 95% $\text{CI}=1.186\text{--}2.009$) and inpatient hospitalizations ($\text{OR}=1.534$; 95% $\text{CI}=1.162\text{--}2.027$). However, neither PM_{10} nor maximum temperature showed a marked association with spontaneous abortion or toxemia of pregnancy in our study population. Our findings suggest that desert dust storms may have an impact on the risk for adverse pregnancy outcomes such as toxemia of pregnancy. Health authorities should take necessary measures to protect pregnant women against detrimental effects of these storms.

Keywords Particulate matter · Toxemia of pregnancy · Spontaneous abortion · Emergency department

✉ Mustafa Bogan
mustafabogan@hotmail.com

Behcet Al
behcetal@gmail.com

Seval Kul
sevalkul@gantep.edu.tr

Suat Zengin
zengins76@hotmail.com

Murat Oktay
mmurat_ok@yahoo.com

Mustafa Sabak
mustafasabak@hotmail.com

Hasan Gümüőboęa
profhasan@hotmail.com

Hasan Bayram
habayram@ku.edu.tr

¹ Department of Emergency Medicine, School of Medicine, Düzce University, 81620 Düzce, Turkey

² Emergency Department of Medicine Faculty, Gaziantep University, 27070 Gaziantep, Turkey

³ Biostatistics Department of Medicine Faculty, Gaziantep University, 27070 Gaziantep, Turkey

⁴ Emergency Department of Medicine Faculty, Gaziantep University, 27100 Gaziantep, Turkey

⁵ Vocational High School, Hasan Kalyoncu University, 27000 Gaziantep, Turkey

⁶ Emergency Department of Medicine Faculty, Gaziantep University, 27705 Gaziantep, Turkey

⁷ Emergency Department of Şehitkamil State Hospital, 27500 Gaziantep, Turkey

⁸ Department of Pulmonary Medicine Koç University Research Center for Translational Medicine (KUTTAM), School of Medicine, Koç University, Istanbul, Turkey

Introduction

The inhalation of pollutants that are dispersed in the atmosphere is thought to affect human health adversely. Meteorological factors such as winds, temperature, pressure, and humidity also cause these pollutants to impact areas which are far from their sources. The impacts of these pollutants on environment and human health vary depending on the type of pollutant, its amount in the atmosphere, and length of time in the atmosphere (Teacer 2009).

Maternal and infant mortality are two of the parameters that show the development level of countries. Abortion and toxemia of pregnancy (preeclampsia/eclampsia) are among the most significant causes of maternal and infant mortality. The loss of fetuses, which weigh below 500 g or for which the gestation period is less than 20 weeks, is defined as abortion (Büyükkurt et al. 2007). Preeclampsia is a significant cause of mortality and morbidity for both mother and fetus. After week 20 of pregnancy, detection of the following should suggest preeclampsia: >160 mmHg systolic blood pressure or >110 mmHg diastolic blood pressure measured twice at intervals of at least 6 h in a sitting position; pulmonary edema, epigastric or right upper quadrant pain; abnormal results in liver function tests; thrombocytopenia; fetal growth disorder; oliguria (<500 mL at 24 h); and proteinuria (Bozdogan 2015). In addition to the results above, eclampsia is diagnosed if convulsions occur (Yıldırım et al. 2011).

There are several studies reporting that particulate matter (PM) exposure during pregnancy, increases the risk of both toxemia of pregnancy and spontaneous abortion (Wang et al. 2018; Grippo et al. 2018; Dastoorpoor et al. 2017; Ha et al. 2018). Similarly, studies reported that increased temperatures were associated with increased number of stillbirth (Rammah et al. 2019; Basu et al. 2016) and miscarriage (Sun et al. 2020; Asamoah et al. 2007) toxemia of pregnancy and spontaneous abortion. However, few studies reported controversial findings about the impact of desert dust storms on adverse pregnancy outcomes, and although a positive association between dust events and preterm births (Viel et al. 2019) and low birth weight (Moreira et al. 2020) was reported, no relationship between desert dust storms and preeclampsia was found (Dadvand et al. 2011).

Gaziantep is the 8th biggest city in Turkey, and it is located in the South East Turkey, close to the Syrian border. It is among the most polluted cities in Turkey (Köne and Büke 2012; Who-Breathlife. 2020). The annual mean concentration of inhaled particulate matter with a diameter $\leq 10 \mu\text{m}$ (PM_{10}) in Turkish city centers in 2000 was $49 \mu\text{g}/\text{m}^3$. This was much higher in Gaziantep ($55 \mu\text{g}/\text{m}^3$) (Köne and Büke 2012). These concentrations are more than double of the annual mean WHO standard, which is $20 \mu\text{g}/\text{m}^3$ (WHO. 2005). Recent data from WHO sponsored “BreatheLife - A global campaign for clean air” has reported the annual $\text{PM}_{2.5}$ levels for Gaziantep as

$66 \mu\text{g}/\text{m}^3$, $6.6 \times$ the $10 \mu\text{g}/\text{m}^3$ WHO guideline (Who-Breathlife. 2020). The city is under the risk of desert dust storms like the other Southeastern Anatolian provinces in Turkey (Baltaci 2017). Gaziantep and these provinces in Southeast Turkey are under effects of dust storms originating from deserts located in the Middle East’s Syrian desert and Africa’s Saharan desert (Baltaci 2017; Bayram and Öztürk 2014; Perfumo and Marchant 2010). Study suggests that the frequency of desert dust storms have increased in the Middle East (Ganor et al. 2010). Recently, we have investigated effects of desert dust storms, PM_{10} and maximum temperature on morbidity and mortality due to cardiovascular diseases, and we found that desert dust storms, PM_{10} levels and maximum temperature were associated with increased ER visits and hospitalization due to acute coronary syndrome. Additionally, PM_{10} and maximum temperature led to increased mortality associated with acute coronary syndrome (Al et al. 2018).

To our knowledge, there are no studies investigating impact of desert dust storms, meteorological parameters, or air pollution on abortion or toxemia of pregnancy in Gaziantep, South East Turkey. This study is designed to examine the effects of the desert dust storms, PM_{10} levels, and daily mean-maximum temperature on spontaneous abortion and toxemia of pregnancy in Gaziantep. Our findings suggest that desert dust, increased PM levels, and temperature changes impact admissions and hospitalizations associated with toxemia of pregnancy and spontaneous abortion.

Methods

This study was conducted retrospectively in Gaziantep after obtaining the approval of the ethics committee. The study was performed in pursuance of the Declaration of Helsinki Protocols. The study examined patient admission and hospitalization records in Avukat Cengiz Gökçek Maternity Hospital and Gaziantep University Medical Faculty Hospital in Gaziantep. Data records were collected from January 1, 2009, to March 31, 2014.

Inclusion criteria Patients over 18 years of age, with a confirmed pregnancy through laboratory tests and sonography, with developed spontaneous abortion before a duration of 20 weeks, and confirmed with laboratory results and sonography, and patients diagnosed with toxemia of pregnancy beyond 20 weeks were included in this study.

Meteorological parameters and detection of particulate matter The highest, the lowest, and average temperature values as well as humidity, pressure, and wind velocity data for the relevant dates were obtained from the General Directorate of Meteorology. Information on daily of PM_{10} values in Gaziantep was obtained from the Air Quality Laboratory of

the Ministry of Environment and Urbanization. Information regarding daily desert dust storms within the dates of the study period were obtained from the website <http://earthobservatory.nasa.gov/>, a website owned and operated by NASA. Daily aerosol optical depth (AOD) over land and ocean mean values was obtained for the coordinates of Gaziantep city. AOD values indicate how much direct sunlight is prevented from reaching the ground by these aerosol particles. An increased AOD value indicates more dust and haze in the atmosphere (NOAA Research 2020; Wilcox et al. 2010). As reported by the National Oceanic and Atmospheric Administration, an AOD of 0.01 corresponds to an extremely clean atmosphere, and a value of 0.4 corresponds to a very hazy condition. In the present study, we used an AOD value >0.5 as an indicator of desert dust storm day. Additionally, the presence of desert dust storm days was also confirmed by the records of Gaziantep Airport, Gaziantep, Turkey.

Data classification Disease groups, date of admission, daily PM_{10} , dust storm dates and maximum daily temperature data were tabulated.

Statistical method Normal distribution of the data was tested using the Shapiro–Wilk test. The Student’s *T*-test and Mann–Whitney *U* test were used in the comparison of two independent groups of variables with normal or without normal distribution, respectively. Generalized Additive Poisson Regression models (Aldrin and Hobæk Haff 2005; Ravindra et al. 2019) were utilized to analyze the impact of the daily effect of PM_{10} levels, and the lag effect in the subsequent three days (lag 0 = day zero; lag 1 = day one; lag 2 = day two, lag 3 = day three of high PM_{10} levels, respectively), daily maximum temperature (MT0= day zero (0) of maximum temperature levels), and presence of dust storm (DS0= day zero (0) of dust storms) on admission and hospitalization and mortality due to spontaneous abortion and toxemia of pregnancy. Log link family was used for smoothing function and penalized smoothing splines were used to adjust for seasonal patterns and long-term trends in disease morbidity adding time as a smoothing variable. All univariate statistical analyses were performed by SPSS for Windows (version 24.0) and generalized additive Poisson regression models were applied by *mgcv* package in R (version 3.4.1) for generalized additive modeling (GAM). The GAM command in *mgcv* was applied to solve the smoothing parameter estimation problem by using the generalized cross-validation (GCV) criterion. Best degree of freedom was automatically selected by GCV based on Un-Biased Risk Estimator (UBRE) criterion. Adjusted odds ratios (ORs) and 95% confidence interval (CI) estimates were calculated to show the direction of the effects.

Results

Eighty-six desert dust storms were identified from September 1, 2009, to January 31, 2014 (1916 days in total). In total, 6410 hospital admission cases were included in this study. Among those cases, 6053 of them were abortion cases, and the mean age of the patients was 28.3 years. Three hundred and fifty-seven cases had toxemia of pregnancy and the mean age was 34.5 years. Of the cases of toxemia of pregnancy, 181 (50.7%) underwent outpatient treatment, and 176 (49.3%) received inpatient treatment (Table 1).

Table 2 shows the descriptive statistics for pollutants and meteorological variables in days with dust storms comparing to no dust storm days. The mean, minimum and maximum temperatures were significantly higher in dust storm days ($P<0.001$), as compared to no dust storm days, and air pressure (mbar) was significantly lower ($P<0.001$), when a dust storm was present. PM_{10} levels and relative humidity between dust storms days, and no dust storm days did not show any significant difference.

As can be seen in Table 3, there were not large differences in the PM_{10} -associated odds across spontaneous abortion cases on day 0 (PM_{10} -lag 0, OR=0.999; 95% CI=0.998–0.999), day 2 (PM_{10} -lag 2, OR=0.998; 95% CI=0.997–0.999), and day 3 (PM_{10} -lag 3, OR=0.998, CI=0.998–0.999). Similarly, increases in maximum temperature was not associated with a meaningful change in spontaneous abortion (OR=0.991, 95% CI=0.988–0.993). When dust storm days were examined, a similar result was observed (OR=0.980; 95% CI=0.977–0.983) (Table 3).

The analysis of data on toxemia of pregnancy did not demonstrate a marked difference in PM_{10} -associated odds ratios (PM_{10} -lag 3, OR=1.003; 95% CI=1.000–1.006), either. However, although daily maximum temperature increase did not show a meaningful effect, presence of dust storms positively associated with toxemia of pregnancy both in outpatient admissions (OR=1.543 95% CI=1.186–2.009) and inpatient hospitalizations (OR=1.534; 95% CI=1.162–2.027) (Table 3).

Discussion

For the first time, the effects of desert dust storms, PM_{10} pollution and daily temperatures on spontaneous abortions and toxemia of pregnancy in Gaziantep, Southeast Turkey were investigated in this study. Although, there was no marked difference in the relation between PM_{10} levels, desert dust storms and maximum temperature and spontaneous abortion, dust storms were positively associated with toxemia of pregnancy. Our findings suggest that desert dust storms have adverse effects on obstetric morbidity.

Although natural dust sources such as desert dusts can contribute to the PM pollution (Dadvand et al. 2011), whose

Table 1 Descriptive statistics

Parameter median (IQR)	<i>n</i>
Cases	Total=6410 (abortions=6053; toxemia of pregnancy= 357)
Age	28.65 (18–59)
PM10 ($\mu\text{g}/\text{m}^3$)	72 (48–115)
Mean temp ($^{\circ}\text{C}$)	14.5 (7.6–24.5)
Max. temp ($^{\circ}\text{C}$)	21.8 (12.6–31.8)
Min. temp ($^{\circ}\text{C}$)	9.1 (4–17.8)
Relative humid.	60.3 (41–79)
Air pressure (mbar)	915.7 (912.3–919.75)
Total days/dust storm days	1916/89

adverse effects on pregnancy are well described (Hu et al. 2014; Enkhmaa et al. 2014; Pedersen et al. 2014), the data on impact of desert dust on obstetric pathologies are limited (Dadvand et al. 2011; Viel et al. 2019; Moreira et al. 2020). In a study that observed 909 pregnant women, there was a positive association between PM_{10} levels and intense dust events and all preterm births (Viel et al. 2019). Similarly, Moreira et al. (2020) reported that desert dust intrusion or advections were associated with low birth weight and preterm weight (Moreira et al. 2020). Our data indicating an increased risk of toxemia of pregnancy in both outpatients and inpatients associated with desert dust storms complement these findings. In contrast, a study by Dadvand et al. (2011) could not identify a relationship between desert dust storms and preeclampsia, which is a pregnancy-induced complication. On the other hand, our data on spontaneous abortion did not show an association with desert dust storms. We think lifestyle and cultural aspects of the local population including staying inside and limitation in physical activity, which can decrease the adverse events related to pregnancy (El-Metwalli et al. 2001), on desert dust days might have a protective effect. We also assume that some women, who had bleeding during early pregnancy, did not present to a hospital.

Epidemiological evidence has revealed that PM_{10} and $\text{PM}_{2.5}$ exposure during pregnancy may lead to fetal death, low birth weight, intrauterine growth retardation and preterm birth (Rudra et al. 2011; Bell et al. 2010; Salam et al. 2005). Similarly, PM exposure during pregnancy was associated with increases in the risk of toxemia of pregnancy and spontaneous abortion (Enkhmaa et al. 2014; Wang et al. 2018; Grippo et al. 2018; Dastoorpoor et al. 2017; Ha et al. 2018). However, our findings did not show a marked change in the risk of toxemia of pregnancy or spontaneous abortions. A reason for such a discrepancy between our data and those of others could be due to small sample size, as our data were obtained from two public hospitals out of all public hospitals and private clinics in Gaziantep city center. Other factors could be the traditional attitudes of the public or local cultural features, as described above.

Studies suggest that the content, size and nature of particles may modulate toxicity of particles (Bayram et al. 1998; Alfaro-Moreno et al. 2007; Kwon et al. 2020). It has been shown that $\text{PM}_{2.5}$ may be more harmful to health, because of their larger surface area and smaller size (Kwon et al. 2020). In our study, we studied effects of PM_{10} , which may systemically be less effective than $\text{PM}_{2.5}$ particles that can be

Table 2 Descriptive statistics for pollutants and meteorological variables

Variables	Overall (<i>n</i> =1916 days)	Dust storms present (<i>n</i> =89 days)	No dust storms (<i>n</i> =1827 days)	<i>P</i>
Median (IQR)				
PM10 ($\mu\text{g}/\text{m}^3$)	72 (48–115)	74 (53.25–135)	72 (48–114)	0.227
Mean temp ($^{\circ}\text{C}$)	14.5 (7.6–24.5)	21.8 (16.7–27)	13.9 (7.3–24.2)	0.001*
Max. Temp ($^{\circ}\text{C}$)	21.8 (12.6–31.8)	28.55 (23.42–34.57)	21.2 (12.4–31.6)	0.001*
Min. Temp ($^{\circ}\text{C}$)	9.1 (4–17.8)	16.1 (10.8–21.3)	8.7 (3.9–17.6)	0.001*
Relative humid.	60.3 (41–79)	53 (40.7–77.3)	60.85 (41–79.3)	0.288
Air pressure (mbar)	915.7 (912.3–919.75)	913.4 (910.8–916.05)	915.9 (912.4–919.9)	0.001*

IQR, inter-quartile range

*Significant at 0.05 level; Mann-Whitney *U* test

Table 3 Results of generalized additive Poisson models for predicting the number of emergency room visits and hospitalization due to obstetric diseases

	Spontaneous abortion (<i>n</i> =6053)			TPOP (<i>n</i> =181)			TPIP (<i>n</i> =176)		
	ORs	95% CI		ORs	95% CI		ORs	95% CI	
PM10-lag 0	0.999	0.998	0.999	1.000	0.996	1.004	1.000	0.996	1.004
PM10-lag 1	1.001	1.000	1.001	0.998	0.993	1.003	0.999	0.994	1.004
PM10-lag 2	0.998	0.997	0.999	1.001	0.997	1.005	1.002	0.998	1.007
PM10-lag 3	0.998	0.998	0.999	1.003	1.000	1.006	0.998	0.994	1.002
MT0	0.991	0.988	0.993	1.006	0.988	1.023	0.991	0.974	1.008
DS0	0.980	0.977	0.983	1.543	1.186	2.009	1.534	1.162	2.027

TPOP, toxemia of pregnancy-Out patients; *TPIP*, toxemia of pregnancy in patients; *ORs*, odds ratios; *MT0*, day zero (0) of maximum temperature levels; *DS0*, day zero (0) of dust storms

inhaled deep into alveoli, enter into the circulation, and then travel to organs and systems, where they can show detrimental effects (Alfaro-Moreno et al. 2007; Kwon et al. 2020). Unfortunately, it was not possible to study impact of PM_{2.5}, since only PM₁₀ has been monitored at the local monitoring station in Gaziantep city center, and only the data on PM₁₀ parameter were available during the study period. Moreover, in vitro human cell studies demonstrated that content and compounds adsorbed on particles such as polyaromatic hydrocarbons could play a role in the toxicity of particles (Bayram et al. 1998). Dust content also may modulate detrimental effect of particles. For example, it has been reported that inhaled PM₁₀ were more toxic for days with intrusion of Saharan dust compared to those without (Moreira et al. 2020). In our study, although PM₁₀ did not show an effect, desert dust markedly associated with toxemia of pregnancy in both out- and inpatients. However, in the current study, it was not possible to analyze particle content either during or out of dust storm days.

It is known that exposure to high temperatures increases pregnancy losses in mammals (Jaichansukkit et al. 2017; Iida and Koketsu 2015; Asamoah et al. (2007). In a study by Rahman et al. (2017), the body temperature of pregnant women, who were exposed to external heat, could reach a level causing fetal destruction or anomaly. In a study examining 1382 materials of spontaneous abortion, Talukder et al. (2007) concluded that spontaneous abortions were more frequent in hot seasons. A study by Janani and Changae (2017) suggested that the incidence of preeclampsia increased in hot seasons. However, Asamoah et al. (2007) could not find a significant correlation between exposure to high temperatures and pregnancy losses in their study conducted in Ghana. In our study, the maximum temperature did not show a meaningful effect on toxemia of pregnancy or the number of spontaneous abortions. Although we have no clear explanation for such a condition, as aforementioned, traditional behaviors such as staying inside in a city with hot temperatures on warm days, the use of air conditioning indoor, as well as paying

attention to medical and non-medical precautions and warnings by health authorities might have a protective effect.

Conclusion

Although our study did not demonstrate a significant association between PM₁₀ pollution and meteorological factors such as maximum temperature on the risk for adverse pregnancy outcomes, desert dust showed a modest effect on the increased risk for toxemia of pregnancy in Gaziantep, Southeast Turkey. Health authorities should warn pregnant women to stay at home, whenever there are dust storms. Policy makers and health authorities should take necessary measures to protect pregnant women against detrimental effects of these storms. Further actions should be taken to mitigate global climate change worldwide.

Limitations of the study

A major limitation of our study may be the small size of the study population from two public hospitals out of more than 30 hospitals and private clinics, where pregnant women could apply during the study period. Thus, our findings may not be able to represent the entire population of Gaziantep city.

Availability of data and materials Raw data are available for editor on request.

Declarations

Ethics approval The study was approved by Ethics Committee of Gaziantep University, Gaziantep province, Turkey (Date: 23.06.2014; Decision No.: 228).

Informed consent Retrospective study.

Human rights The authors declare that human rights were respected according to Declaration of Helsinki.

Conflict of interest The authors declare no competing interests.

References

- Al B, Bogan M, Zengin S, Sabak M, Kul S, Oktay MM et al (2018) Effects of dust storms and climatological factors on mortality and morbidity of cardiovascular diseases admitted to ED. *Emerg Med Int*:3758506. <https://doi.org/10.1155/2018/3758506>
- Aldrin M, Hobæk Haff I (2005) Generalised additive modelling of air pollution, traffic volume and meteorology. *Atmos Environ* 39: 2145–2155. <https://doi.org/10.1016/j.atmosenv.2004.12.020>
- Alfaro-Moreno E, Nawrot TS, Nemmar A, Nemery B (2007) Particulate matter in the environment: pulmonary and cardiovascular effects. *Curr Opin Pulm Med* 13(2):98–106. <https://doi.org/10.1097/MCP.0b013e328013f47e>
- Asamoah B, Kjellstrom T, Östergren PO (2007) Is ambient heat exposure levels associated with miscarriage or stillbirths in hot regions? A cross-sectional study using survey data from the Ghana Maternal Health Survey 2007. *Int J Biometeorol* 62(3):319–330. <https://doi.org/10.1007/s00484-017-1402-5>
- Baltaci H (2017) Spatial and temporal variation of the extreme Saharan dust event over Turkey in March 2016. *Atmosphere* 8:41. <https://doi.org/10.3390/atmos8020041>
- Basu R, Sarovar V, Malig BJ (2016) Association between high ambient temperature and risk of stillbirth in California. *Am J Epidemiol* 183(10):894–901. <https://doi.org/10.1093/aje/kwv295>
- Bayram H, Öztürk AB. (2014). Global climate change, desertification, and its consequences in Turkey and the Middle East. In *Global Climate Change and Public Health*. New York, NY, Humana Press, pp 293–305
- Bayram H, Devalia JL, Sapsford RJ, Ohtoshi T, Miyabara Y, Sagai M, Davies RJ (1998) The effect of diesel exhaust particles on cell function and release of inflammatory mediators from human bronchial epithelial cells in vitro. *Am J Respir Cell Mol Biol* 18:441–448. <https://doi.org/10.1165/ajrmb.18.3.2882>
- Bell ML, Belanger K, Ebisu K, Gent JF, Lee HJ, Koutrakis P, Leaderer BP (2010) Prenatal exposure to fine particulate matter and birth weight: variations by particulate constituents and sources. *Epidemiology* 21(6):884–891. <https://doi.org/10.1097/EDE.0b013e3181f2f405>
- Bozdag H (2015) The frequency and fetomaternal outcomes of early-and late-onset preeclampsia: the experience of a single tertiary health center in the bustling metropolis of Turkey; Istanbul. *Medeniyet Med J* 30(4):163–169. <https://doi.org/10.5222/MMJ.2015.163>
- Büyükkurt S, Güzel AB, Demir SC, Kadayıfçı O (2007) Spontaneous abortion; etiology: maternal factors (anatomic defects, uterine abnormalities, cervical insufficiency). *Türkiye Klinikleri. J Surg Med Sci* 3(5):12–16
- Dadvand P, Basagaña X, Figueras F, Amoly E, Tobias A, de Nazelle A, Querol X, Sunyer J, Nieuwenhuijsen MJ (2011) Saharan dust episodes and pregnancy. *J Environ Monit* 13(11):3222–3228. <https://doi.org/10.1039/c1em10579e>
- Dastoorpoor M, Idani E, Goudarzi G, Khanjani N (2017) Acute effects of air pollution on spontaneous abortion, premature delivery, and stillbirth in Ahvaz, Iran: a time-series study. *Environ Sci Pollut Res Int* 25(6):5447–5458. <https://doi.org/10.1007/s11356-017-0692-9>
- El-Metwalli AG, Badawy AM, El-Baghdadi LA, El-Wehady A (2001) Occupational physical activity and pregnancy outcome. *Eur J Obstet Gynecol Reprod Biol* 100(1):41–45. [https://doi.org/10.1016/s0301-2115\(01\)00419-5](https://doi.org/10.1016/s0301-2115(01)00419-5)
- Enkhmaa D, Warburton N, Javzandulam B, Uyanga J, Khishigsuren Y, Lodoysamba S, Enkhtur S, Warburton D (2014) Seasonal ambient air pollution correlates strongly with spontaneous abortion in Mongolia. *BMC Pregnancy Childbirth* 14(1). <https://doi.org/10.1186/1471-2393-14-146>
- Ganor E, Osetinsky I, Stupp A, Alpert P (2010) Increasing trend of African dust, over 49 years, in the eastern Mediterranean. *J Geophys Res Atmos* 115(D7). <https://doi.org/10.1029/2009JD012500>
- Grippo A, Zhang J, Chu L, Guo Y, Qiao L, Zhang J, Myneni AA, Mu L (2018) Air pollution exposure during pregnancy and spontaneous abortion and stillbirth. *Rev Environ Health* 33(3):247–264. <https://doi.org/10.1515/reveh-2017-0033>
- Ha S, Sundaram R, Louis GMB, Nobles C, Seeni I, Sherman S et al (2018) Ambient air pollution and the risk of pregnancy loss: a prospective cohort study. *Fertil Steril* 109(1):148–153. <https://doi.org/10.1016/j.fertnstert.2017.09.037>
- Hu H, Ha S, Roth J, Kearney G, Talbott EO, Xu X (2014) Ambient air pollution and hypertensive disorders of pregnancy: a systematic review and meta-analysis. *Atmos Environ* 97:336–345. <https://doi.org/10.1016/j.atmosenv.2014.08.027>
- Iida R, Koketsu Y (2015) Climatic factors associated with abortion occurrences in Japanese commercial pig herds. *Anim Reprod Sci* 157: 78–86. <https://doi.org/10.1016/j.anireprosci.2015.03.018>
- Jaichansukkit T, Suwanasopee T, Koonawootrittriron S, Tummaruk P, Elzo MA (2017) Effect of daily fluctuations in ambient temperature on reproductive failure traits of Landrace and Yorkshire sows under Thai tropical environmental conditions. *Trop Anim Health Prod* 49(3):503–508. <https://doi.org/10.1007/s11250-017-1221-z>
- Janani F, Changae F (2017) Seasonal variation in the prevalence of preeclampsia. *J Family Med Prim Care* 6(4):766–769. https://doi.org/10.4103/jfmpc.jfmpc_132_17
- Köne AÇ, Büke T (2012) A comparison for Turkish provinces' performance of urban air pollution. *Renew Sust Energ Rev* 16:1300–1310. <https://doi.org/10.1016/j.rser.2011.10.006>
- Kwon HS, Ryu MH, Carlsten C (2020) Ultrafine particles: unique physicochemical properties relevant to health and disease. *Exp Mol Med* 52:318–328. <https://doi.org/10.1038/s12276-020-0405-1>
- Moreira I, Linares C, Follos F, Sánchez-Martínez G, Vellón JM, Díaz J (2020) Short-term effects of Saharan dust intrusions and biomass combustion on birth outcomes in Spain. *Sci Total Environ* 701: 134755. <https://doi.org/10.1016/j.scitotenv.2019.134755>
- Pedersen M, Stayner L, Slama R, Sørensen M, Figueras F, Nieuwenhuijsen MJ, Raaschou-Nielsen O, Dadvand P (2014) Ambient air pollution and pregnancy-induced hypertensive disorders. *Hypertension* 64(3):494–500. <https://doi.org/10.1161/HYPERTENSIONAHA.114.03545>
- Perfumo A, Marchant R (2010) Global transport of thermophilic bacteria in atmospheric dust. *Environ Microbiol Rep* 2(2):333–339. <https://doi.org/10.1111/j.1758-2229.2010.00143.x>
- Rahman J, Fakhruddin SHM, Rahman AKMF, Halim MA (2017) Environmental heat stress among young working women: a pilot study. *Ann Glob Health* 82(5):760. <https://doi.org/10.1016/j.aogh.2016.07.007>
- Rammah A, Whitworth KW, Han I, Chan W, Hess JW, Symanski E (2019) Temperature, placental abruption and stillbirth. *Environ Int* 131:105067. <https://doi.org/10.1016/j.envint.2019.105067>
- Ravindra K, Rattan P, Mor S, Aggarwal AN (2019) Generalized additive models: Building evidence of air pollution, climate change and human health. *Environ Int* 132:104987
- NOAA Research. (2020). NOAA Earth System Research Laboratory Global Monitoring Division. <https://www.esrl.noaa.gov/gmd/grad/surftraid/aod/>. Access 03 Mar 2020
- Rudra CB, Williams MA, Sheppard L, Koenig JQ, Schiff MA (2011) Ambient carbon monoxide and fine particulate matter in relation to preeclampsia and preterm delivery in Western Washington State.

- Environ Health Perspect 119(6):886–892. <https://doi.org/10.1289/ehp.1002947>
- Salam MT, Millstein J, Li YF, Lurmann FW, Margolis HG, Gilliland FD (2005) Birth outcomes and prenatal exposure to ozone, carbon monoxide, and particulate matter: results from the Children’s Health Study. *Environ Health Perspect* 113:1638–1644. <https://doi.org/10.1289/ehp.8111>
- Sun X, Luo X, Cao G, Zhao C, Xiao J, Liu X et al (2020) Associations of ambient temperature exposure during pregnancy with the risk of miscarriage and the modification effects of greenness in Guangdong, China. *Sci Total Environ* 702:134988. <https://doi.org/10.1029/2009JD012500>
- Talukder S, Haque M, Huq M, Alam M, Roushan A, Noor Z, Nahar K (2007) Histopathological analysis of hysterectomy specimens. *Mymensingh Med J* 16(1):81–84. <https://doi.org/10.3329/mmj.v16i1.254>
- Tecer LH (2009) A factor analysis study: Air pollution, meteorology, and hospital admissions for respiratory diseases. *Toxicol Environ Chem* 91(7):1399–1411. <https://doi.org/10.1080/02772240902732316>
- Viel J, Mallet Y, Raghoumandan C, Quénel P, Kadhel P, Rouget F et al (2019) Impact of Saharan dust episodes on preterm births in Guadeloupe (French West Indies). *Occup Environ Med* 76:336–340. <https://doi.org/10.1136/oemed-2018-105405>
- Wang Q, Zhang H, Liang Q, Knibbs LD, Ren M, Li C et al (2018) Effects of prenatal exposure to air pollution on preeclampsia in Shenzhen, China. *Environ Pollut* 237:18–27. <https://doi.org/10.1016/j.envpol.2018.02.010>
- WHO (2005) WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide Global update 2005. Summary of risk assessment. World Health Organization, Geneva, Switzerland, pp 5–18
- WHO-Breathlife. (2020). The air pollution in Gaziantep, Turkey. https://breathlife2030.org/city_data/gaziantep/
- Wilcox EM, Lau KM, Kim KM (2010) A northward shift of the North Atlantic Ocean Intertropical Convergence Zone in response to summertime Saharan dust outbreaks. *Geophys Res Lett* 37(4). <https://doi.org/10.1029/2009GL041774>
- Yıldırım G, Güngördük K, Aslan H, Gül A, Bayraktar M, Ceylan Y (2011) Comparison of perinatal and maternal outcomes of severe preeclampsia, eclampsia, and HELLP syndrome. *J Turk Ger Gynecol Assoc* 12(2):90–96. <https://doi.org/10.5152/jtgga.2011.22>

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.