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Research Article

Impact of Ambient Air Pollutants and Extreme Temperatures on Pregnancy Outcomes: A Clinical-Epidemiological Case-Control Study

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Abstract

Background: The interaction between environmental issues and maternal-fetal health is a pressing social health issue, which is intensified by climatic change. The major risk factors in relation to negative pregnancy outcomes in Iraq are air pollutants and temperature changes. ***Objective***: To investigate the impact of environmental pollution and extreme temperatures on pregnancy outcomes (preterm birth and congenital anomalies). ***Methods***: The study was a case-control study involving 180 pregnant women (90 cases, 90 controls) in Basrah Maternity and Children's Hospital. The exposure to pollutants and heat was measured using the GIS and multivariate logistic regression models. ***Results***: In the case group, $PM_{2.5}$ (46.4µg/m³) and NO_2 (30.0µg/m³) were significantly higher as compared to controls. The statistical analysis revealed that each one-unit increase in $PM_{2.5}$ increased the likelihood of adverse pregnancy outcomes by 8%, and NO_2 increased the likelihood by 20%. Importantly, a one-degree Celsius increase in maximum temperature increased the risk by 53%. The first and the third trimesters were confirmed as the critical periods of extreme environmental sensitivity. Exposure to pollutants and heat in these trimesters had close relations with preterm birth and congenital anomalies and a synergistic impact of high temperatures and toxicity of pollutants on increasing health risks. ***Conclusions***: There is a strong relationship between ambient atmospheric pollutants and extreme heat and the risks of poor pregnancy in Basrah, and those environmental and health programs should be implemented timely to stem the effects on pregnant women.

Keywords: Ambient atmospheric pollutants; Climate change; Particulate matter; Pregnancy outcomes; Preterm birth.

تأثير ملوثات الهواء المحيطة ودرجات الحرارة الشديدة على نتائج الحمل: دراسة حالة وشواهد سريرية وبائية

الخلاصة

الخلفية: التفاعل بين الملوثات البيئية وصحة الأم والجنين هو قضية صحية اجتماعية ملحة، تزداد حدتها التغيرات المناخية. العوامل الرئيسية للخطر المتعلقة بنتائج الحمل السلبية في العراق هي ملوثات الهواء وتغيرات درجات الحرارة. **الهدف**: دراسة تأثير التلوث البيئي ودرجات الحرارة الشديدة على نتائج الحمل (الولادة المبكرة والشذوذات الخلقية). **الطرائق**: كانت دراسة حالة وشاهد شملت 180 امرأة حامل (90 حالة، 90 ضابطة) في مستشفى الولادة والأطفال في البصرة. تم قياس التعرض للملوثات والحرارة باستخدام نظم المعلومات الجغرافية ونماذج الانحدار اللوجستي متعددة المتغيرات. **النتائج**: في مجموعة الحالات، كانت $PM_{2.5}$ (46.4 ميكروغرام/م³) وNO_2 (30.0µg/m³) أعلى بشكل ملحوظ مقارنة بالمجموعات الضابطة. كشف التحليل الإحصائي أن كل زيادة وحدة واحدة في $PM_{2.5}$ تزيد من احتمال حدوث نتائج سلبية للحمل بنسبة 8٪، وزيادة NO_2 الاحتمالية بنسبة 20٪. ومن المهم أن زيادة درجة الحرارة القصوى بمقدار درجة مئوية واحدة زادت من الخطر بنسبة 53٪. تم تأكيد أن الثلثين الأول والثالث كانا فترتين حرجة من حساسية البيئة القصوى. كان التعرض للملوثات والحرارة في هذه الثلاثيات مرتبطا ارتباطا وثيقا بالولادة المبكرة والشذوذات الخلقية، وتأثير تآزري لدرجات الحرارة العالية وسمية الملوثات على زيادة المخاطر الصحية. **الاستنتاجات**: هناك علاقة قوية بين الملوثات الجوية المحيطة والحرارة الشديدة ومخاطر الحمل السيء في البصرة، ويجب تنفيذ تلك البرامج البيئية والصحية في الوقت المناسب للحد من التأثيرات على النساء الحوامل.

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INTRODUCTION

Environmental determinants are a critical issue in the field of public health with a significant impact on the health of the mother and fetus, exacerbated by current climatic change. Atmospheric pollutants and extreme temperature changes consistently link to adverse pregnancy outcomes [1]. Therefore, a comprehensive understanding of the epidemiological, clinical, and biological mechanisms mediating the relationship between these exposures and maternal physiological processes is crucial. The physiological changes inherent to pregnancy intensify the vulnerability of pregnant women to air pollution and thermal extremes, which highlights the need to incorporate environmental stewardship into primary healthcare. These issues are exacerbated by both natural and anthropogenic environmental factors in the Middle East and North Africa. Systematic reviews also indicate a growing burden of disease caused by atmospheric pollutants and

climate change that leads to more mortality and morbidity [2]. Women, fetuses, and children are disproportionately affected by these effects. Long-term exposure to air pollutants can trigger developmental disorders, genetic mutations, and other adverse perinatal outcomes [3]. Exposure to environmental pollution is associated with adverse outcomes such as low birth weight and preterm birth. Empirical evidence from highly polluted urban centers, such as Isfahan, reveals a strong correlation between ambient pollutant levels during gestation and high rates of preterm births [4]. Similarly, findings from Ahvaz demonstrate a direct relationship between exposure to pollutants, infant low birth weight, and the prevalence of preterm births [5]. These observations highlight the urgent need for implementing strict environmental policies. Global warming, characterized by rising temperatures and more frequent heatwaves, represents a significant environmental hazard. Meta-analyses conducted in low- and middle-income countries indicate a positive correlation between ambient temperature rise and the rates of spontaneous abortion, preterm birth, and stillbirth [6]. Physiological responses to thermal stress in pregnant women can impede oxygen and nutrient delivery to the fetus, potentially triggering premature uterine contractions [6]. In Iraq, this threat is compounded by the interplay of armed conflict, environmental degradation, and climatic factors. This ecological degradation coupled with the rise in heavy-metal and chemical pollution has been attributed to an increase in adverse birth outcomes and congenital anomalies linked to war-related pollution as recorded after the 1991 Gulf War [7]. Consequently, Iraq presents a compelling case for studying the nexus of heat stress and chemical contamination. Research in Iraq reveals a complex epidemiological situation that requires significant interventions. In particular, it has been found that there is a strong association between the prevalence of congenital anomalies in specific provinces and sustained exposure to different environmental pollutants [8]. Addressing this situation requires a multidisciplinary approach that integrates chemical exposure, climatic processes, socioeconomic factors, and health care accessibility. Reviews of Eastern Mediterranean countries have affirmed that outdoor and indoor air pollutants and passive smoking are also important determinants of low birth weight, spontaneous abortions, and respiratory diseases in children [9]. These findings underscore the need for advanced environmental monitoring systems. The swift climate change in the Arabian Peninsula has triggered significant ecological changes, which have given rise to new health and economic issues. Evidence suggests a convergence of factors that elevates the risk of non-communicable diseases in pregnant populations because of atmospheric ambient pollutants and climate change [10]. A study carried out in Abu Dhabi suggests ambient environmental and sociocultural factors as the main cause of preterm birth, and ambient conditions are the most significant variables [11]. These works point to the international aspect of environmental problems, which requires regional cooperation. Both the health of the mother and the fetus are at risk in Iraq and the rest of the Arab states due to the threat of chemical contamination and high temperatures. Particularly, the following have been empirically associated with negative pregnancy outcomes: heavy metals, particulate matter, and persistent organic pollutants [12]. It highlights the necessity of more specific clinical and epidemiological studies to outline the underlying biological and molecular pathways and to come up with effective adaptive responses. The current study aims to fill this evidence gap by carrying out a detailed clinical-epidemiological assessment of the interactive effects of environmental pollutants and extreme temperatures on pregnancy outcomes in the Iraqi context.

METHODS

Study design

This is a clinical-epidemiological case-control study that was aimed at establishing the cause-and-effect relationship between exposure to environmental pollutants and extreme temperatures with poor pregnancy outcomes. The comparative framework allows a strict evaluation of the exposure differentials between the women who have had adverse pregnancy outcomes and those who had healthy pregnancies.

Setting and participants

The study was conducted in Basrah Maternity and Children's Hospital in Basrah Governorate, Iraq, where the levels of industrial activity and the extreme temperatures of the seasons are quite high. The study was planned to be conducted between January 2025 and December 2025. A total of 180 pregnant women were recruited for the study, who were divided strategically into two groups to compare them. It consisted of the case group of 90 pregnant women with adverse pregnancy outcomes, i.e., preterm birth, low birth weight, or congenital anomalies. The control group was comprised of 90 healthy pregnant women with normal progression of the pregnancy who were able to give birth to healthy normal full-term children within the same geographical location and, similarly, within the same time period. The ratio (1:1) is created to provide adequate statistical power that can determine the significant environmental and climatic risk factors.

Inclusion criteria

Pregnant women in their first trimester were included in the study, meaning they had to be at least 12 weeks of

gestation at the time of recruitment. To be eligible, participants must have lived at least one year in the specified area of study before conception to avoid being newly moved to a new environment. Moreover, the participants should be aged 18 to 40 years, show the willingness and capability to give informed consent, and have the intention of giving birth to their child within the identified locales of the study, which are hospitals. In the case of the control group, it was limited to people who had no previous pregnancy complications and a healthy clinical picture.

Exclusion criteria

Participants with pre-existing chronic conditions, such as severe hypertension or diabetes, were excluded, as these conditions are known to have a strong effect on the outcome of pregnancy, like severe hypertension, diabetes mellitus, or autoimmune diseases. In addition, cases of multiple gestations, i.e., twins or triplets, and pre-diagnosis of genetic or chromosomal abnormalities not related to environmental conditions were excluded from the study. Women who had a history of substance abuse, such as smoking, alcohol, or illicit drug use during pregnancy, were not eligible. Lastly, those who move out of the study region within the time of their pregnancy or who have incomplete medical records and are unable to undergo follow-up were excluded from the final analysis.

Data collection procedure

A multi-faceted approach was used to collect the data, and it will entail a combination of clinical assessment, environmental monitoring, and the administration of detailed questionnaires. Baseline demographic, socioeconomic, and medical history information was gathered at the time of recruitment and was gathered with the help of structured interviews. During pregnancy, the participants were subjected to routine antenatal visits whereby clinical data such as the gestational age, maternal weight gain, and any pregnancy complications were assessed. The birth outcomes, including preterm birth (less than 37 weeks of gestation), low birth weight (weight of the baby at birth less than 2500 grams), and existence of congenital anomalies, were carefully recorded at birth and in the immediate postnatal period. These outcomes were defined as per the standardized definitions of the established international health protocols to be used in ensuring consistency and comparability with other international epidemiology studies [13].

Environmental exposure assessment

The exposure to environmental pollutants was measured by implementing a combination of methods. The ambient atmospheric pollutants data that were collected consisted of the levels of particulate matter, nitrogen dioxide, sulfur dioxide, and ozone found in the recognized governmental environmental monitoring stations situated in the study area. This information was associated with the residential addresses of participants with geographical information systems (GIS) and sophisticated exposure modeling methods, as have been applied in past high-impact studies that have examined the ambient atmospheric pollutants and birth outcomes [14]. In the case of extreme temperature exposure, the values of daily maximum and minimum ambient temperature and heat index values were obtained from local meteorological stations. The cumulative and peak heat exposures during the critical periods of pregnancy were determined at the residential areas of individual participants, based on existing methodologies from systematic reviews on heat exposure and pregnancy outcomes [15].

Outcome measurements

The hospital records of delivery and postnatal follow-up were used to determine pregnancy outcomes. Live birth below 37 weeks of gestation was considered preterm birth. Low birth weight was determined to refer to any weight below 2500 grams at birth. Pediatricians use the standard diagnostic criteria to diagnose congenital anomalies and will classify them based on the codes of the International Classification of Diseases. The outcome data was checked by a trained study team to guarantee accuracy and completeness of all outcome data, and it was done independently according to the validated clinical epidemiological assessment protocols [16].

Ethical considerations

The study protocol was approved by the Research Ethics Committee of the Basrah Health Directorate, in accordance with protocol EC/08/25, on January 15, 2025. Participants were informed of the study's status and gave verbal consent before enrolling.

Statistical analysis

Demographic characteristics, exposure levels, and pregnancy outcomes were summarized using descriptive statistics. Preliminary associations were examined using bivariate analyses. The independent effects of environmental pollution factors and extreme temperature on the likelihood of adverse pregnancy outcomes were analyzed using multivariate logistic regression models, controlling the possible confounding factors (maternal age, parity, socioeconomic status, and smoking status). All statistical tests were conducted

using corresponding statistical programs with the significance level of $p< 0.05$.

RESULTS

Table 1 shows a summary of both cases and control groups in terms of demographic and socioeconomic backgrounds. The mean age of the two groups did not differ statistically; thus, the two groups were homogeneous in terms of their age. The distribution of parity and SES did not differ significantly between the cases and the controls.

Table 1: Baseline demographic and socioeconomic characteristics of study participants (n= 90 in each group)

Variable	Case	Control
Age (year)	27.5±4.6	27.2±3.9
Parity (Median [Range])	3.0 [0-4]	2.0 [0-4]
SES Low	37.8	40.0
SES Medium	40.0	36.7
SES High	22.2	23.3

Values are presented as frequency, percentage and mean±SD. SES: socioeconomic status.

Figure 1 demonstrates that $PM_{2.5}$ and nitrogen dioxide (NO_2) levels were higher in the control group compared to the case.

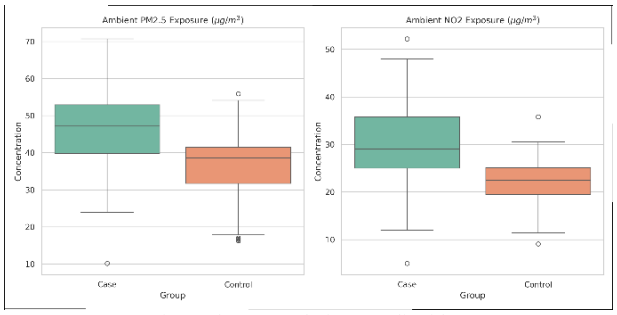

Figure 1: Comparison of $PM_{2.5}$ and nitrogen dioxide (NO_2) exposure levels between case and control groups.

The $PM_{2.5}$ (46.4 ± 8.3 µg/m³) and NO_2 (30 ± 7.0 µg/m³) were significantly higher in the case group than in the control group ($PM_{2.5}$: 36.5 ± 8.3 µg/m³; NO_2: 22 ± 5.0 µg/m³). Such results suggest a relationship between high exposure of these pollutants and poor pregnancy outcomes. In Figure 2, the distribution of maximum daily temperatures is given between the two groups. The case group had a higher mean temperature (38.1 ± 3.1 °C) than the control group (35.2±1.7 °C) to prove the hypothesis that extreme temperatures may be a contributory factor in adverse pregnancy outcomes. The independent effects of environmental pollutants and extreme temperatures on the probability of adverse pregnancy outcomes were assessed by means of multivariable logistic regression models, controlling the possibility of the presence of other potential confounding variables: age and socioeconomic status.

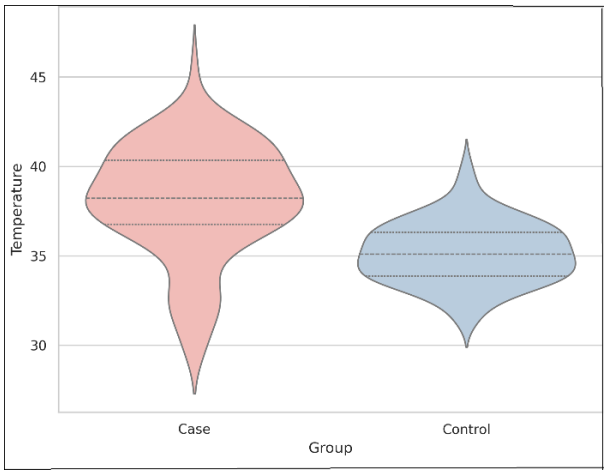

Figure 2: Distribution of mean daily maximum temperatures between case and control groups.

According to the findings of Table 2, the exposure to $PM_{2.5}$, NO_2, and the mean temperature were found to have a significant correlation with the high likelihood of an unfavorable outcome in pregnancy.

Table 2: Multivariable logistic regression analysis for adverse pregnancy outcomes

Variable	Odds Ratio (OR)	95% CI (Lower)	95% CI (Upper)	*p*-value
Constant	5.10e-11	1.99e-14	1.30e-07	<0001
$PM_{2.5}$	1.08	1.04	1.13	<0001
NO_2	1.20	1.11	1.29	<0001
Mean Temperature	1.53	1.29	1.81	<0001
Age	1.02	0.92	1.13	<0001
High Socioeconomic Status	0.88	0.28	2.72	0.823
Medium Socioeconomic Status	0.79	0.31	2.01	0.615

These findings imply that every one-unit change in the $PM_{2.5}$ concentration causes a probability of experiencing adverse pregnancy outcomes to go up by 8% (OR= 1.08, 95% CI: 1.04-1.13, p= 0.0001). In the same way, a unit change in the concentration of NO_2 raises the risk of adverse pregnancy outcomes by 20% (OR= 1.20, 95% CI: 1.11-1.29, $p< 0.0001$). Moreover, a one-degree Celsius increase in the mean temperature augurs the probability of poor results in pregnancy by 53% (OR= 1.53, 95% CI: 1.29-1.81, $p< 0.0001$). Other factors, including age and socioeconomic status, did not play a significant role in this model because of adverse pregnancy outcomes. The correlation matrix of $PM_{2.5}$ levels with temperatures during the first, second, and third trimesters of the pregnancy is shown in Figure 3. The correlation matrix shows that there are strong positive correlations between the levels of $PM_{2.5}$ in the first, second, and third trimesters and that there are

strong positive correlations between the temperatures of the first, the second, and the third trimesters.

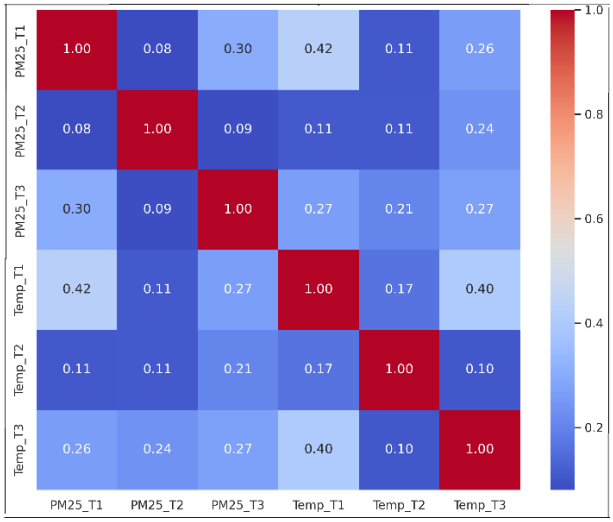

Figure 3: Correlation matrix of environmental exposure across different pregnancy trimesters.

The relationship between $PM_{2.5}$ and the same trimester temperatures is also moderate, which implies the possibility of interactions between them to influence the pregnancy outcomes. Odds ratios (OR) were determined to determine the effects of exposure to environmental pollutants and temperature variations on the fetus during crucial periods in any trimester, i.e., in $PM_{2.5}$ and temperature. A forest plot of these odds ratios is shown in Figure 4.

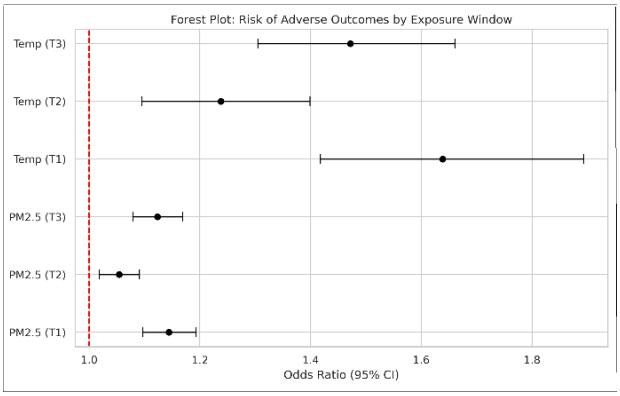

Figure 4: Forest plot of odds ratios (OR) for adverse pregnancy outcomes by exposure window ($PM_{2.5}$ and temperature).

According to the results, the level of $PM_{2.5}$ exposure during the first and third trimesters of pregnancy and temperature exposure during the first and third trimesters is associated significantly with adverse pregnancy outcomes. In other instances, the effect of the second trimester exposure was less evident or non-significant. In Table 3, we compare the levels of $PM_{2.5}$ and temperature exposure during the first trimester of pregnancy regarding specific adverse outcome groups (preterm birth, low birth weight, and congenital anomaly) and the control group. The findings indicate that women who had preterm birth, low birth weight, or congenital abnormalities were exposed to greater mean $PM_{2.5}$ and temperatures during the first trimester than those exposed to the control group.

Table 3: $PM_{2.5}$ and temperature exposure levels in the first trimester of pregnancy by adverse outcome type

Outcome	$PM_{2.5}$	Temperature
Preterm birth	48±12	39±4.0
Low birth weight	42±10	36±3.0
Congenital anomaly	45±11	38±4.0
Control	35±8.0	34±3.0

Values are presented as mean±SD.

DISCUSSION

This study provides a comprehensive clinical-epidemiological assessment of the effects of environmental contaminants and exposure to extreme temperatures in relation to adverse pregnancy outcomes in Basrah City. A strong and independent relationship was found between high concentrations of $P_{M2.5}$ in the air, nitrogen dioxide (NO_2), and extreme heat conditions during critical gestational periods and the incidence of preterm birth (PTB), low birth weight (LBW), and congenital anomalies. These findings are consistent with the growing body of international literature that highlights the susceptibility of the health of both mother and child to the impacts of climate change and degradation of the urban environment [17]. As is revealed in our analysis, the concentration of $PM_{2.5}$ and NO_2 was significantly higher in the case group than in the control group. The multivariate logistic regression equation has confirmed that with each one-unit change in $PM_{2.5}$, the odds of adverse outcomes were raised by 8 points. This is in line with recent systematic reviews that have hypothesized that prenatal exposure to fine particulate matter has the potential to induce systemic oxidative stress and placental inflammation, thus resulting in poor fetal growth and early-term labor [18]. These pollutant levels are usually magnified by industrial operations and seasonal dust storms in Iraq, posing a long-term environmental dilemma for pregnant women living in urban centers [19]. One important revelation of the study is the strong impact of the exposure to extreme temperatures. We have noted that every 1°C rise in maximum temperature was accompanied by a 53% rise in the risk of unfavorable pregnancy outcomes. This impact is quite alarming considering the increasing pattern of the heat waves in the Middle East. The biologic processes through which heat causes negative effects can include dehydration, decreased uterine blood flow, and the secretion of oxytocin and prostaglandins, which can initiate uterine contractions [20]. The findings of our study also point out that the first and third trimesters are especially delicate critical periods, in which heat exposure is most associated with preterm delivery and birth defects [21]. The subgroup analysis showed that women who gave birth to children with congenital defects or low birth

weight were significantly exposed to both $PM_{2.5}$ and extreme heat in the first trimester. This is in line with the hypothesis that early-stage organogenesis is extremely vulnerable to environmental injuries. Even though other researchers in Iraq were interested in the issue of heavy metal contamination during the conflict, our data indicates that modern ambient atmospheric pollutants in cities and increased temperature are becoming major causes of reproductive health risks [22]. The positive relationship between heat pollution and ambient atmospheric pollutants, as demonstrated by our correlation table, shows a compounding relationship, as high temperatures may increase the toxicity of ambient pollutants or vice versa, which is becoming more frequently reported in low- and middle-income countries [23]. Moreover, we controlled for socioeconomic status (SES) and maternal age in our study and discovered that the environmental signal was still prominent despite the significance of these factors. This implies that the urban environment in Iraq is a universal threat to pregnant women irrespective of their economic status, although lower SES groups may have fewer means to counteract exposure to air conditioning or residential transfer [24]. This is why the overall high level of exposure at the baseline of the studied urban center may explain the lack of a significant relationship between SES and our regression model, which consequently levels the risk across various strata [25]. To sum up, this study demonstrated an urgent need to implement public health interventions and environmental policies, as well as to decrease maternal exposure to pollution and excessive heat. With the ongoing rise in temperature in the area due to climate change, the health of both the mother and the neonatal system should be a priority in city planning and clinical practice discussions. These findings provide robust evidence for healthcare providers to integrate environmental counseling into prenatal care, encouraging pregnant women to avoid outdoor activities when pollution and heat are at their peak, especially in the first and third trimesters [8].

Study limitations

There are a number of limitations that can be identified in this study, and they should be taken into account when interpreting the results. The first limitation was environmental exposure estimated using data from stationary monitoring stations associated with residential addresses through GIS. This method fails to consider individual-level variation in exposure, including the length of time spent indoors, workplace exposures, and individual mobility patterns, which may result in exposure misclassification. Second, although we considered some of the most important confounders (age, socioeconomic status), we were unable to capture all possible sources of variation, such as maternal nutrition, psychological stress, and indoor air quality. Third, the sample of 180 participants, though statistically sufficient to address the main aims, might not provide an in-depth look into unusual cases of congenital abnormalities. Lastly, the study was conducted in only one city in Iraq, Basrah, and the results might not be entirely applicable to rural or other industrial and climatic regions.

Conclusion

This study confirms that ambient air pollutants ($PM_{2.5}$ and NO_2) and exposure to extreme temperatures play an important role in increasing the risk of adverse pregnancy outcomes in Basrah City. The third and first trimesters were identified as the most susceptible to these environmental stressors. These results highlight an urgent social health issue because increasing temperatures and urban pollution growth still pose a threat to the health of both mothers and infants. Policy interventions are urgently needed to enhance air quality and establish heat-adaptation strategies specifically designed to support pregnant women. Further investigation into the complex effects of a combination of several environmental stressors and reproductive health needs to be improved through personal monitoring methods and larger cohorts in future studies.

Conflict of interests

The authors declared no conflict of interest.

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Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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