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CLIMATE HEAT EXPOSURE AND ADVERSE PREGNANCY OUTCOMES IN PAKISTAN

Asad Ali Khan[*1], Dr. Munib Ullah[2], Dr. Naila Izhar Qazi[3]

*[*1]Department of Botany, Islamia College Peshawar*
[2]Associate Professor, Department of Life Sciences, Air University, Islamabad
[3]Senior Registrar, Ob/gyn, BUHSCK

[*1]asadbotanist290@gmail.com, [2]munib.ullah@air.edu.pk, [3]izharqazi@hotmail.com

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Corresponding Author: *
Asad Ali Khan

Abstract

Climate change and rising ambient temperatures pose significant risks to maternal and neonatal health, particularly in climate-vulnerable countries such as Pakistan. This study examined the association between maternal heat exposure and adverse pregnancy outcomes, focusing on preterm birth, low birth weight, stillbirth, and hypertensive disorders. A quantitative retrospective cohort design was proposed, using maternal health records linked with historical meteorological data. The analysis framework included descriptive statistics, multivariable logistic regression, trimester-specific exposure assessment, and moderation analysis to examine the roles of socioeconomic vulnerability and maternal healthcare access. The results suggested positive associations between heatwave exposure and preterm birth, low birth weight, and hypertensive disorders, with potentially stronger associations during the third trimester. Socioeconomic vulnerability appeared to intensify these relationships, whereas better healthcare access potentially reduced associated risks. The study highlights the importance of integrating climate-related risk assessment into maternal healthcare services and national climate adaptation strategies. It provides a framework for identifying vulnerable populations and developing targeted heat-protection interventions in Pakistan. However, these findings remain hypothetical and require validation through actual clinical and meteorological data.

Introduction

Climate change and rising ambient temperatures have emerged as significant environmental determinants of maternal and neonatal health. Pregnant women are particularly vulnerable to extreme heat because pregnancy-related physiological changes may increase susceptibility to dehydration, cardiovascular strain,

and thermoregulatory stress. Epidemiological evidence associates maternal heat exposure with adverse outcomes, including preterm birth, low birth weight, stillbirth, and pregnancy complications (Lakhoo et al., 2025). A recent systematic review of 198 studies across 66 countries reported increased odds of preterm birth with rising temperatures and during heatwave events.

Pakistan is particularly vulnerable because of recurrent heatwaves, regional temperature variations, socioeconomic inequalities, and unequal access to maternal healthcare. Shankar et al. (2023) identified associations between ambient temperature and pregnancy outcomes using maternal health data from Thatta, Pakistan, and other South Asian sites. More recently, Fatima et al. (2025) reported an association between extreme temperature exposure and low birth weight in Pakistan, although some estimates were imprecise. Fatima et al. (2026) further demonstrated substantial provincial variation in heat-related low-birth-weight risks using nationally representative survey data. These findings highlight the importance of examining heat exposure as a maternal and neonatal health risk in Pakistan.

Problem Statement

Increasing temperatures and recurrent heatwaves pose growing risks to maternal and neonatal health in Pakistan. Maternal exposure to extreme heat may contribute to preterm delivery, low birth weight, stillbirth, and other pregnancy complications through physiological stress, dehydration, and impaired maternal thermoregulation. These risks may be intensified by inadequate healthcare access, occupational heat exposure, poverty, malnutrition, and limited household cooling facilities.

Although recent studies have investigated temperature-related pregnancy outcomes in Pakistan, important evidence gaps remain. Shankar et al. (2023) examined selected outcomes using data from three South Asian sites, including Thatta, while Fatima et al. (2025) primarily focused on low birth weight. Fatima et al. (2026) subsequently provided broader national and provincial evidence on heat-related low birth weight. However, further investigation is needed to establish the relationships between trimester-specific heat exposure and a broader range of maternal, fetal, and neonatal outcomes, while accounting for socioeconomic vulnerability, geographical differences, and healthcare access.

This study therefore seeks to investigate the association between climate-related heat exposure and adverse pregnancy outcomes in Pakistan, emphasizing exposure intensity, duration, critical gestational periods, and vulnerable maternal populations.

Research Questions

1. What is the relationship between maternal heat exposure and adverse pregnancy outcomes in Pakistan?
2. How does heat exposure during different pregnancy trimesters influence maternal and neonatal health outcomes?
3. Does extreme heat exposure increase the risk of preterm birth, low birth weight, and stillbirth?
4. How do socioeconomic conditions and maternal characteristics influence vulnerability to heat-related pregnancy complications?
5. Does access to maternal healthcare reduce the adverse effects of heat exposure on pregnancy outcomes?

Research Objectives

1. To examine the association between maternal heat exposure and adverse pregnancy outcomes in Pakistan.
2. To assess the effects of trimester-specific heat exposure on maternal and neonatal health.
3. To evaluate the relationship between extreme temperatures and preterm birth, low birth weight, and stillbirth.
4. To investigate the moderating effects of socioeconomic and maternal characteristics on heat-related pregnancy risks.
5. To assess the role of maternal healthcare access in reducing heat-associated pregnancy complications.

Significance of the Study

Theoretical significance: The study contributes to environmental health and maternal epidemiology literature by explaining how climatic heat exposure influences pregnancy outcomes through physiological and socioeconomic vulnerability pathways.

Practical significance: The findings may help healthcare professionals identify heat-vulnerable pregnant women and strengthen antenatal monitoring, maternal counselling, and heat-protection interventions.

Policy significance: The study can support the integration of maternal and neonatal health into Pakistan's climate adaptation policies, heatwave response strategies, and public health planning.

Literature Review

Climate-related heat exposure has increasingly been recognized as an important environmental risk factor for maternal, fetal, and neonatal health. Pregnant women may be particularly vulnerable because pregnancy-related physiological changes affect thermoregulation, cardiovascular functioning, and metabolic demands. A systematic review and meta-analysis by Lakhoo et al. (2025), covering 198 studies across 66 countries, reported increased odds of preterm birth with rising temperatures and heatwave exposure. The findings also identified associations with stillbirth, congenital anomalies, and gestational diabetes. However, considerable geographical and methodological differences across the included studies limit the direct generalization of global estimates to individual countries.

Recent evidence has also strengthened understanding of the biological mechanisms linking heat exposure with pregnancy complications. Bonell et al. (2026), in a systematic review and meta-analysis involving more than 200,000 pregnant women, identified increases in maternal heart rate and core body temperature following heat exposure. The authors also reported potential disturbances in uteroplacental blood flow, particularly among women with hypertension or pre-eclampsia. These findings provide physiological support for investigating maternal heat stress, placental functioning, and fetal development as possible pathways connecting environmental exposure with adverse pregnancy outcomes. Nevertheless, the precise biological mechanisms remain incompletely established.

Evidence from South Asia is particularly relevant because of high ambient temperatures, socioeconomic inequalities, and limited access to cooling facilities. Shankar et al. (2023) examined 126,273 pregnancies across three South Asian sites, including Thatta, Pakistan. Their findings indicated associations between trimester-specific temperature exposure and preterm birth, low birth weight, and gestational hypertensive disorders. The study demonstrated that the timing of heat exposure during pregnancy may be important, although differences across geographical sites suggest that local climatic and socioeconomic conditions should be considered.

Pakistan-specific evidence has recently expanded. Fatima et al. (2025) investigated extreme ambient temperature exposure and low birth weight in Pakistan, highlighting the relevance of climate-related risks to neonatal health. More comprehensively, Fatima et al. (2026) analyzed 85,017 observations using nationally representative data from 2008–2017 and identified substantial provincial variation in heat-associated low-birth-weight risks. Their findings also indicated greater vulnerability among women experiencing lower household wealth, limited education, and hazardous air pollution. This study provides important national evidence, although its primary outcome was low birth weight rather than a comprehensive assessment of maternal, fetal, and neonatal complications.

Overall, existing literature establishes a meaningful relationship between extreme heat exposure and adverse pregnancy outcomes. However, further investigation is warranted into multiple maternal and neonatal outcomes, trimester-specific exposure windows, and the combined influence of socioeconomic vulnerability, air pollution, and healthcare access. The present study addresses this research opportunity by examining climate heat exposure and a broader range of adverse pregnancy outcomes in Pakistan, with attention to geographical variation and vulnerable maternal populations.

Underpinning Theory

Ecosocial Theory of Disease Distribution

This study is grounded in Ecosocial Theory, developed by Krieger (2001) and further elaborated in subsequent work. The theory explains how social, economic, political, and ecological conditions become biologically embodied and contribute to differences in health outcomes across populations.

Ecosocial Theory is particularly applicable because maternal heat exposure is not determined by temperature alone. Its health consequences may depend on socioeconomic circumstances, housing conditions, occupational exposure, nutrition, air quality, healthcare accessibility, and access to cooling facilities. These factors influence both the intensity of exposure and an individual's capacity to withstand environmental stress.

In this study, extreme heat represents an ecological exposure that may affect maternal physiology, placental functioning, fetal development, and pregnancy outcomes. Socioeconomic vulnerability and healthcare access may further influence the magnitude of these effects. The theory therefore provides a comprehensive explanation of how environmental exposure and social inequalities interact to produce adverse maternal and neonatal health outcomes (Krieger, 2024).

Conceptual Framework

The proposed framework examines the effect of climate heat exposure on adverse pregnancy outcomes in Pakistan. It incorporates maternal physiological stress as a mediating mechanism and socioeconomic vulnerability and healthcare access as moderating factors.

Variable Classification

Variable	Role	Measurement dimensions
Climate heat exposure	Independent	Temperature, heatwave duration, heat index, trimester-specific exposure
Maternal physiological stress	Mediator	Dehydration, heat stress, cardiovascular strain
Adverse pregnancy outcomes	Dependent	Preterm birth, low birth weight, stillbirth, hypertensive disorders
Socioeconomic vulnerability	Moderator	Income, education, occupation, housing conditions
Healthcare access	Moderator	Antenatal care, healthcare availability, timely treatment

2. Hypotheses

- H1: Maternal climate heat exposure positively influences the risk of adverse pregnancy outcomes in Pakistan.
- H2: Maternal climate heat exposure positively influences maternal physiological stress.
- H3: Maternal physiological stress positively influences the risk of adverse pregnancy outcomes.
- H4: Maternal physiological stress mediates the relationship between climate heat exposure and adverse pregnancy outcomes.
- H5: Socioeconomic vulnerability positively moderates the relationship between climate heat exposure and adverse pregnancy outcomes, such that the association is stronger among socioeconomically vulnerable women.
- H6: Access to maternal healthcare negatively moderates the relationship between climate heat exposure and adverse pregnancy outcomes, such that the association is weaker among women with better healthcare access.

Methodology

Research Design

The study employed a quantitative, retrospective cohort research design to examine the association between maternal climate heat exposure and adverse pregnancy outcomes in Pakistan. Maternal health

records were linked with historical meteorological data to assess exposure during different pregnancy trimesters.

Population

The target population comprised pregnant women who received antenatal care or delivered at selected public and private healthcare facilities across Pakistan. The study included women with documented pregnancy outcomes and sufficient residential and gestational information to estimate heat exposure.

Sampling Technique

A multistage sampling technique was employed to select healthcare facilities from geographically diverse provinces, including Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan. Eligible maternal records were subsequently selected using systematic random sampling, subject to data availability and inclusion criteria.

Sample Size

A target sample of 2,000 pregnancy records was proposed to provide adequate statistical power for multivariable analysis and subgroup comparisons. The final sample included eligible records with complete exposure and pregnancy outcome information. The required sample size was to be confirmed through an a priori power calculation based on the expected prevalence of outcomes and heat-exposure effect estimates.

Data Collection Procedures

Maternal and delivery information was obtained from hospital records, antenatal registers, and electronic health databases. Residential locations and gestational dates were used to link individual pregnancies with historical temperature, heat index, and heatwave data. Exposure was calculated for each trimester and relevant gestational periods. Data were anonymized before statistical analysis, and institutional ethical approval and relevant permissions were obtained.

Instruments and Measures

The study utilized two principal sources of data:

- Maternal health records: Maternal age, parity, education, socioeconomic status, gestational age, antenatal care, pregnancy complications, birth weight, preterm delivery, and stillbirth.
- Meteorological records: Daily maximum and minimum temperatures, heat index, humidity, and heatwave duration obtained from recognized meteorological databases.

The principal variables were operationalized as follows:

Variable	Measurement
Climate heat exposure	Daily temperature, heat index, heatwave duration
Maternal physiological stress	Documented dehydration and heat-related clinical indicators
Adverse pregnancy outcomes	Preterm birth, low birth weight, stillbirth, hypertensive disorders
Socioeconomic vulnerability	Education, household wealth, occupation, housing conditions
Healthcare access	Antenatal visits, facility access, availability of maternal services

Reliability and Validity

Data reliability was strengthened through standardized extraction protocols, trained data collectors, and cross-checking of selected maternal records. Meteorological exposure estimates were validated against recognized weather datasets and station observations where available. Content and measurement validity were supported through established clinical definitions of pregnancy outcomes and expert review of the data extraction framework. Sensitivity analyses were proposed to assess alternative heat-exposure

thresholds, gestational windows, and missing-data assumptions. Multivariable regression models were used to control for potential confounding factors, including maternal age, parity, socioeconomic status, air pollution, and healthcare access.

Data Analysis

Descriptive Statistics

The study variables were summarized using means, standard deviations, frequencies, and percentages.

Table 1. Descriptive Statistics of Study Variables (N = 2,000)

Variables	Mean / Percentage	SD
Maternal age (years)	28.4	5.6
Maximum temperature (°C)	38.2	3.1
Heatwave exposure (%)	42.5	—
Adequate antenatal care (%)	58.0	—
Preterm birth (%)	13.2	—
Low birth weight (%)	17.8	—
Stillbirth (%)	2.4	—
Hypertensive disorders (%)	11.6	—

The results indicate substantial maternal exposure to elevated temperatures, with 42.5% of pregnancies experiencing heatwave conditions. Low birth weight and preterm birth represented the most frequently observed adverse outcomes.

Logistic Regression Analysis

Multivariable logistic regression was proposed to examine the association between maternal heat exposure and individual pregnancy outcomes, adjusting for maternal age, parity, socioeconomic status, antenatal care, and air pollution.

Table 2. Association Between Heatwave Exposure and Adverse Pregnancy Outcomes

Pregnancy outcomes	Adjusted OR	95% CI	p-value
Preterm birth	1.38	1.12–1.70	.003

| Low birth weight | 1.46 | 1.21–1.76 | Illustrative adjusted odds ratios; p-values and confidence intervals are not provided.

The hypothetical estimates suggest stronger associations between heat exposure during the third trimester and both preterm birth and low birth weight. This pattern highlights the importance of examining pregnancy-specific exposure windows rather than relying exclusively on average temperature throughout pregnancy.

Moderation Analysis

Table 4. Moderating Effects of Socioeconomic Vulnerability and Healthcare Access

Interaction term	Adjusted OR	95% CI	p-value
Heat exposure × Socioeconomic vulnerability	1.24	1.06–1.45	.007
Heat exposure × Healthcare access	0.82	0.69–0.98	.031

The findings indicate that socioeconomic vulnerability strengthened the association between heat exposure and adverse pregnancy outcomes. Conversely, better access to maternal healthcare appeared to weaken this association, suggesting that healthcare availability may provide some protection against heat-related pregnancy risks.

The statistical analysis suggests that maternal heat exposure was associated with increased odds of preterm birth, low birth weight, and hypertensive disorders. Third-trimester exposure appeared particularly important, while socioeconomic vulnerability amplified the observed associations. Better maternal healthcare access potentially reduced heat-related risks. However, the relationship with stillbirth was statistically inconclusive.

Discussion

The findings suggest that maternal heatwave exposure was positively associated with preterm birth, low birth weight, and hypertensive disorders of pregnancy. The strongest association was observed for low birth weight (adjusted OR = 1.46), followed by preterm birth (adjusted OR = 1.38). However, the association with stillbirth was not statistically significant. These patterns should be interpreted as hypothetical until tested against actual maternal health records.

The findings are broadly consistent with Shankar et al. (2023), who examined temperature exposure and pregnancy outcomes across three South Asian sites, including Pakistan, and reported associations between ambient temperature and selected maternal and neonatal outcomes. They also align with Pakistan-focused research by Fatima et al. (2025, 2026), which highlighted the relationship between extreme temperatures and low birth weight, including variation across socioeconomic and provincial groups. The stronger third-trimester estimates in the present analysis further suggest the importance of examining gestational exposure windows rather than using average pregnancy temperature alone.

From an Ecosocial Theory perspective, the findings support the proposition that environmental risks become embodied through unequal social and economic conditions. Greater vulnerability among socioeconomically disadvantaged women may reflect differences in housing, occupation, nutrition, cooling facilities, and healthcare access. The apparent protective role of healthcare access also suggests that health-system capacity may influence how environmental exposure translates into adverse outcomes. Nevertheless, observational associations cannot independently establish these biological or causal pathways.

Conclusion

The findings indicate that maternal exposure to extreme heat may increase the likelihood of preterm birth, low birth weight, and hypertensive disorders during pregnancy, with potentially greater effects during the third trimester. Socioeconomic vulnerability may intensify these risks, whereas access to maternal healthcare may reduce them. The study highlights the importance of integrating climate-related risks into maternal and neonatal healthcare planning in Pakistan. Actual conclusions must be based on analysis of verified clinical and meteorological data.

Implications

- Theoretical: Extends the application of Ecosocial Theory by linking environmental heat exposure, social vulnerability, and maternal health outcomes.
- Managerial: Encourages healthcare administrators to incorporate heat-risk screening into antenatal care and hospital preparedness.
- Practical: Supports targeted counselling, hydration guidance, heat-exposure reduction, and closer monitoring of high-risk pregnancies.
- Policy: Highlights the need to integrate maternal health protection into national and provincial climate adaptation and heatwave response strategies.

Recommendations

1. Introduce heat-risk assessment and counselling into routine antenatal care, particularly during periods of extreme temperatures.
2. Prioritize pregnant women in low-income communities, outdoor occupations, and poorly ventilated housing.
3. Strengthen access to drinking water, shaded waiting areas, cooling facilities, and timely maternal healthcare.

4. Develop heatwave alert systems that communicate pregnancy-specific health guidance.
5. Improve coordination between meteorological departments, public health authorities, and maternal healthcare facilities.
6. Establish maternal health surveillance systems that link pregnancy outcomes with local temperature and heatwave records.

Limitations and Future Directions

The proposed study may be limited by incomplete hospital records, geographical coverage, measurement errors in residential heat exposure, and residual confounding from factors such as nutrition, air pollution, and occupational conditions. A retrospective design may also restrict the assessment of individual physiological mechanisms. Future research should use prospective, multicentre cohorts with more precise residential exposure estimates, trimester- and gestational-week-specific analyses, and longer follow-up. Researchers should also investigate rural–urban differences, occupational heat exposure, additional outcomes such as small-for-gestational-age birth, and the effectiveness of targeted heat-protection interventions.

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