

The Impact of Heatwave Exposure and Climate Change on Maternal Health and Pregnancy Outcomes: A Public Health Review

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ABSTRACT

Background: Climate change is increasing the frequency, intensity, and duration of extreme heat events. Pregnancy is a heat-vulnerable physiological state because maternal cardiovascular, metabolic, and thermoregulatory demands rise while fetal development depends on stable uteroplacental function. *Purpose:* This review synthesizes evidence on heatwave exposure, maternal health, pregnancy outcomes, biological pathways, vulnerable populations, and public-health responses. *Methods:* A narrative public-health review was conducted using peer-reviewed systematic reviews, meta-analyses, cohort studies, and authoritative guidance, with emphasis on evidence published from 2020 to 2025 while retaining selected earlier landmark studies. *Results:* The strongest and most consistent evidence concerns preterm birth. A 2025 meta-analysis of 198 studies from 66 countries reported higher odds of preterm birth with increasing heat exposure and during heatwaves. Evidence also links heat with low birth weight, stillbirth, gestational diabetes, hypertensive disorders, placental complications, and selected congenital anomalies, although effect sizes and certainty vary by outcome. Proposed pathways include dehydration, cardiovascular strain, altered uteroplacental perfusion, inflammation, oxidative stress, endocrine responses, and placental dysfunction. Social disadvantage, outdoor work, poor housing, and limited access to cooling may amplify risk. *Conclusion:* Extreme heat should be incorporated into maternal-health surveillance, antenatal counselling, occupational protection, heat-health warning systems, and climate-resilient health services, especially in tropical and resource-constrained settings.

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INTRODUCTION

Climate change is reshaping the distribution of environmental health risks by increasing average temperatures and intensifying extreme heat events. Heatwaves are occurring against a background of rising baseline temperatures, and in many regions hot nights are also becoming more common. These changes matter for maternal and perinatal health because pregnancy involves substantial cardiovascular, metabolic, endocrine, and thermoregulatory adaptations. International agencies have therefore identified pregnant women, fetuses, newborns, and young children as populations that require explicit attention in climate and health policy (WHO, UNICEF, & UNFPA, 2023).

Pregnancy increases circulatory blood volume, cardiac output, oxygen consumption, and metabolic heat production. At the same time, maternal physiology must preserve placental perfusion and fetal homeostasis. Heat dissipation relies mainly on skin blood flow and sweating. When high ambient temperature is combined with humidity, prolonged physical activity, dehydration, limited ventilation, or inadequate access to cooling, these mechanisms can be strained. Physiological vulnerability may be further modified by gestational age, maternal age, obesity, hypertension, diabetes, anemia, infection, occupational workload, and socioeconomic conditions (Samuels et al., 2022).

Epidemiological evidence linking heat with adverse pregnancy outcomes has expanded rapidly. A major systematic review and meta-analysis published in *Nature Medicine* synthesized 198 studies from 66 countries and identified 23 maternal, fetal, and neonatal outcomes. The authors reported that evidence was strongest for preterm birth, while associations were also observed for stillbirth, low birth weight, gestational diabetes, obstetric complications, and congenital anomalies. Importantly, most included studies were conducted in high-income countries, creating uncertainty about the magnitude of risk in low- and middle-income countries where heat exposure may be more intense and adaptive resources more limited (Lakhoo et al., 2025).

Earlier meta-analytic evidence reached similar conclusions. Chersich et al. (2020) reviewed 70 studies from 27 countries and found that the odds of preterm birth increased by about 5% per 1°C increase in temperature and by about 16% during heatwaves. Stillbirth also increased with rising temperature, while results for birth weight were more heterogeneous. A United States systematic review likewise found frequent associations between heat exposure and preterm birth, low birth weight, and stillbirth, with disparities by race and socioeconomic circumstances reported in several studies (Bekkar et al., 2020).

The public-health significance of these findings extends beyond clinical obstetrics. Heat exposure is shaped by housing, urban form, occupation, access to water and electricity, working conditions, social protection, and health-system preparedness. Consequently, preventing heat-related pregnancy complications requires multilevel interventions rather than relying solely on individual behavior. This review summarizes current evidence on heatwave exposure and maternal health, examines biological and social pathways, identifies major pregnancy outcomes, and discusses priorities for surveillance, prevention, adaptation, and research.



METHODS

1. Review Design and Scope

This article was developed as a narrative public-health review. It does not claim the exhaustive study identification or formal risk-of-bias procedures of a de novo systematic review. Instead, it synthesizes high-level evidence from recent systematic reviews and meta-analyses and uses selected large cohort and case-crossover studies to illustrate specific outcomes and mechanisms.

2. Evidence Sources and Eligibility

Priority was given to peer-reviewed publications addressing ambient temperature, heatwaves, heat stress, or extreme heat during pregnancy and reporting maternal, fetal, placental, birth, or neonatal outcomes. Authoritative guidance from the World Health Organization and related UN agencies was included to frame public-health implications. Evidence published from 2020 to 2025 was emphasized, while earlier landmark studies were retained when they provided important quantitative estimates or mechanistic insights. Outcomes of interest included preterm birth, stillbirth, low birth weight or fetal growth, gestational diabetes, hypertensive disorders, placental complications, congenital anomalies, and heat-related physiological strain.

3. Approach to Synthesis

Findings were organized by exposure pathways, biological plausibility, maternal outcomes, pregnancy and fetal outcomes, population vulnerability, and public-health intervention. Because the underlying studies use different definitions of heat—including absolute temperature, percentile thresholds, apparent temperature, heat index, wet-bulb globe temperature, and heatwave duration—effect estimates are presented as illustrative rather than as universal clinical thresholds. Heterogeneity in climate, acclimatization, exposure assessment, and population characteristics was considered when interpreting associations.

RESULTS

1. Climate Change, Heatwaves, and Exposure During Pregnancy

Heat exposure during pregnancy can be acute, cumulative, occupational, or household-based. Acute exposure may occur during a short heatwave immediately before labor, whereas cumulative exposure may operate over weeks or trimesters. The health effect of a given temperature is also context-dependent: a temperature that is extreme in a temperate region may be common in a tropical setting, while high humidity can substantially reduce evaporative cooling even when air temperature is lower. For this reason, relative thresholds and biothermal indices may be more informative than a single global cut-off.

The exposure metric is a central methodological issue. Many epidemiological studies assign temperature from the nearest weather station or gridded climate product to a residential address. Such methods are practical for large populations but may misclassify individual exposure because indoor temperature, workplace heat, travel, building materials, ventilation, air-conditioning,

clothing, hydration, and physical activity are not captured. These limitations are especially relevant for pregnant workers in agriculture, food services, factories, markets, health care, and other settings where metabolic heat and radiant heat may add to ambient conditions.

2. Biological Plausibility and Maternal-Fetal Pathways

Several pathways plausibly connect environmental heat with adverse pregnancy outcomes. First, peripheral vasodilation redirects blood toward the skin to dissipate heat. When combined with dehydration, this response can reduce effective circulating volume and may alter uteroplacental perfusion. Second, sweating increases water and electrolyte losses; inadequate replacement can contribute to maternal dehydration, renal stress, and cardiovascular strain. Third, heat may trigger inflammatory, oxidative, and endocrine responses that influence vascular function, uterine activity, and placental signaling (Samuels et al., 2022).

Placental function is a particularly important research frontier. A 2024 systematic review examining heat stress and placental outcomes reported changes across placental weight and efficiency, uteroplacental blood flow, placental anatomy, gene expression, and steroid-related pathways in human and animal studies. However, direct human mechanistic evidence remains limited, and much of the detailed biological knowledge is derived from animal models (Ramirez et al., 2024). These findings support biological plausibility but should not be interpreted as proof that a single pathway explains all epidemiological associations.

3. Preterm Birth

Preterm birth is the heat-associated pregnancy outcome with the most consistent evidence. In the 2020 BMJ meta-analysis, the odds of preterm birth increased by approximately 1.05 per 1°C rise in temperature, and heatwave exposure was associated with an odds ratio of approximately 1.16 (Chersich et al., 2020). The larger 2025 meta-analysis reported a similar dose-response pattern, with an odds ratio of approximately 1.04 per 1°C increase and approximately 1.26 during heatwaves (Lakhoo et al., 2025). The consistency of findings across different regions and designs strengthens concern that heat can act as a trigger for earlier delivery.

Individual studies also show that risk is not uniform across pregnant populations. In Northern California, Basu et al. (2017) found associations between apparent temperature and preterm delivery and examined modification by maternal characteristics. Such work suggests that comorbidities and social conditions can alter susceptibility. From a public-health perspective, even modest relative increases may translate into meaningful numbers of additional preterm births when heat exposure affects large populations.

4. Stillbirth, Fetal Growth, and Low Birth Weight

Evidence also links high temperature with stillbirth and impaired fetal growth, although the magnitude and certainty are less uniform than for preterm birth. Chersich et al. (2020) reported that all eight studies in their review assessing stillbirth identified associations with higher temperature, with an estimated increase of about 5% per 1°C rise. Low birth weight was associated with heat in



many studies, but heterogeneity was substantial because fetal growth and gestational duration are influenced by multiple pathways and because studies used different exposure windows.

Evidence from lower-resource settings is particularly important. A systematic review of 11 studies from low- and middle-income countries found that most studies assessing preterm birth, low birth weight, and stillbirth reported heat-related associations, although heterogeneity prevented quantitative pooling (Lakhani et al., 2024). A large South Asian cohort of 126,273 pregnancies from sites in India and Pakistan found that higher trimester-specific temperatures were associated with preterm birth, low birth weight, and gestational hypertensive disease, highlighting the relevance of heat research in populations already exposed to high baseline temperatures (Shankar et al., 2023).

5. Gestational Diabetes and Hypertensive Disorders

Maternal metabolic and vascular outcomes are increasingly studied. In a Canadian cohort of 555,911 births, gestational diabetes prevalence rose from 4.6% among women exposed to very cold mean temperatures before screening to 7.7% among those exposed to hot mean temperatures; each 10°C increase in the preceding 30-day mean temperature was associated with approximately 6% higher adjusted odds of gestational diabetes (Booth et al., 2017). The 2025 meta-analysis also identified an overall association between higher heat exposure and gestational diabetes, although the number of studies contributing to pooled estimates remained relatively small (Lakhoo et al., 2025).

Associations between temperature and hypertensive disorders of pregnancy are more complex because vascular responses may vary by season, gestational period, baseline climate, and maternal susceptibility. Nonetheless, observational studies and the South Asian registry analysis suggest that high temperature can be associated with gestational hypertension or preeclampsia in some exposure windows (Shankar et al., 2023). More prospective studies using individual heat exposure and blood-pressure measurements are needed before clinically specific thresholds can be proposed.

6. Placental Complications and Other Outcomes

Placental abruption is a clinically severe outcome that may be triggered by acute environmental stress. A case-crossover study from Quebec including more than 17,000 cases found that higher temperatures in the week before abruption were associated with greater risk at term, particularly among some socially disadvantaged groups (He et al., 2018). The magnitude was modest, and findings do not establish that heat is a dominant cause of abruption; rather, they support the broader hypothesis that acute thermal stress may precipitate obstetric events among susceptible pregnancies.

Research has also examined congenital anomalies, premature rupture of membranes, neonatal morbidity, neonatal mortality, and other outcomes. The 2022 scoping review identified 18 heat-associated maternal, fetal, and neonatal outcomes across 75 studies, but evidence outside preterm birth, low birth weight, stillbirth, and gestational diabetes was comparatively sparse (Dalugoda et al., 2022). The 2025 meta-analysis reported an association with congenital anomalies

overall, but individual anomaly types were based on fewer studies and should be interpreted cautiously (Lakhoo et al., 2025).

Table 1. Summary of Major Heat-Associated Maternal and Pregnancy Outcomes

Outcome	Overall evidence	Illustrative findings	Public-health interpretation
Preterm birth	Strongest and most consistent	~4-5% higher odds per 1°C increase in major meta-analyses; higher risk during heatwaves	Priority outcome for heat-health surveillance and antenatal counselling
Stillbirth	Consistent signal, fewer studies	~5% higher risk per 1°C increase in the 2020 meta-analysis	Supports rapid heat-risk communication during pregnancy
Low birth weight / fetal growth	Probable association; heterogeneous	Associations reported across high-income and LMIC studies	Requires attention to cumulative exposure and gestational windows
Gestational diabetes	Increasing evidence	Large Canadian cohort: ~6% higher odds per 10°C increase before screening	Consider heat as a contextual risk in maternal metabolic health
Hypertensive disorders	Emerging and context-dependent	Associations reported in trimester-specific and multi-country analyses	More individual-level exposure research is needed
Placental and other obstetric outcomes	Emerging	Heat associated with placental abruption in selected studies; placental functional changes are biologically plausible	Useful for risk stratification, but evidence is not yet sufficient for universal thresholds

7. Vulnerability, Inequality, and Occupational Heat

Heat-related pregnancy risk is socially patterned. Women with limited access to reliable electricity, cooling, safe drinking water, high-quality housing, transportation, and antenatal care have fewer opportunities to avoid exposure. Urban heat-island effects can increase nighttime temperatures in densely built neighborhoods, while rural populations may face long travel distances to health facilities and intensive outdoor work. Low-income workers may also have little control over schedules, rest periods, or productivity targets.

Occupational exposure deserves particular attention because pregnant workers may experience environmental heat and internally generated metabolic heat simultaneously. Protective measures should therefore include accessible drinking water, shaded or cooled rest areas, task rotation, work-rest cycles, flexible scheduling during heat alerts, and mechanisms for clinical



accommodation when symptoms or pregnancy complications occur. Public-health messages that simply instruct pregnant women to 'avoid the heat' are insufficient when employment, caregiving responsibilities, housing, and infrastructure limit personal choice.

8. Public Health Interventions and Climate Adaptation

The evidence supports a layered prevention strategy. At the individual and clinical level, antenatal care can include heat-risk education, hydration advice, recognition of heat illness, review of medications and comorbidities, and clear instructions on when to seek urgent assessment. Advice should be locally appropriate and avoid rigid temperature thresholds that have not been validated for the local climate.

At the community level, heat-health early warning systems should explicitly identify pregnant and postpartum women as vulnerable groups. Alerts can be linked with community health workers, midwives, primary-care facilities, social services, and occupational-health programs. WHO has emphasized the need for maternal, newborn, and child-health indicators and pregnancy-specific consideration in heat early-warning systems (WHO, 2024).

Health facilities themselves must be climate-resilient. Maternity wards, delivery rooms, antenatal clinics, and neonatal units require reliable water, electricity, ventilation, cooling, emergency power, and heat-response plans. Health information systems can link meteorological data with maternal outcomes to identify local risk periods and evaluate whether heat alerts and adaptation measures reduce adverse outcomes.

Table 2. Public Health Actions to Reduce Heat-Related Risks in Pregnancy

Level	Priority actions	Examples
Individual / family	Reduce avoidable heat load and recognize symptoms early	Hydration, rest, cooler indoor space, reduce strenuous activity during peak heat, seek care for heat illness or obstetric warning signs
Antenatal and clinical care	Integrate heat risk into routine maternal services	Heat-risk screening, tailored counselling, closer follow-up for high-risk pregnancies, referral pathways
Workplace	Reduce occupational heat strain	Potable water, shade/cooling, work-rest cycles, schedule modification, pregnancy accommodation
Community	Target vulnerable households during heat alerts	Community outreach, cooling spaces, transport support, messaging through midwives and community health workers
Health system / policy	Build climate-resilient maternal health services	Early warning systems, resilient electricity and water, surveillance, climate-informed emergency planning, urban heat mitigation

DISCUSSION

The current evidence supports extreme heat as a meaningful maternal and reproductive health hazard. The most convincing epidemiological signal is for preterm birth, where multiple systematic reviews, large observational datasets, and recent meta-analysis show broadly consistent associations. Evidence for stillbirth, low birth weight, gestational diabetes, hypertensive disorders, placental complications, and congenital anomalies is also concerning, but certainty varies because the number of studies, definitions of heat, exposure windows, and outcome ascertainment differ.

The 2025 Nature Medicine review is particularly important because it expands the evidence base beyond the traditional focus on preterm birth, low birth weight, and stillbirth. By including 198 studies from 66 countries, it demonstrates that heat-related maternal and neonatal outcomes are not isolated observations. At the same time, the review shows a major equity problem in the evidence itself: high-income and temperate settings remain overrepresented. This matters because populations in tropical LMICs may experience higher baseline heat, more outdoor work, limited cooling, housing-related exposure, and health-system constraints (Lakhoo et al., 2025).

The South Asian and LMIC evidence reinforces the need for locally derived risk estimates rather than simple transfer of thresholds from Europe or North America. Shankar et al. (2023) demonstrated trimester-specific associations in India and Pakistan, while Lakhani et al. (2024) found that most included LMIC studies reported heat-related adverse outcomes. These findings are relevant to other tropical countries, including Indonesia, where maternal health services will increasingly need to account for heat alongside established obstetric risk factors. Local humidity, acclimatization, building design, work patterns, and healthcare access should be incorporated into surveillance and intervention research.

From a mechanistic perspective, the available evidence is biologically coherent. Pregnancy raises metabolic and cardiovascular demands; heat increases skin blood flow and sweat losses; dehydration can reduce plasma volume; and placental perfusion may be affected by circulatory redistribution. Placental research additionally suggests pathways involving blood flow, morphology, gene expression, inflammation, and oxidative stress (Samuels et al., 2022; Ramirez et al., 2024). However, observational associations should not be reduced to a single causal pathway. Heat often co-occurs with air pollution, drought, wildfire smoke, food insecurity, infectious disease risk, and disruptions to water and health services. These interacting exposures can confound or amplify observed effects.

Public-health action should therefore use the precautionary principle without overstating certainty. The goal is not to label every hot day as dangerous, but to reduce avoidable thermal strain, identify people with fewer adaptive resources, and prepare maternal health systems for predictable periods of heat. Heat-health early warning systems can incorporate pregnancy-specific communication, but thresholds should be calibrated to local epidemiology and climate rather than copied from other settings. WHO's work on indicators for extreme heat and maternal, newborn, and child health provides an important framework for this direction (WHO, 2024).

This review has limitations. It is a narrative synthesis and did not conduct an independent systematic search, duplicate screening, or formal risk-of-bias assessment. Effect estimates are drawn



from published reviews and illustrative studies that vary in exposure definition and study design. Most research estimates outdoor ambient temperature rather than personal heat dose, leaving uncertainty around indoor heat, occupational exposure, hydration, air-conditioning, and behavioral adaptation. In addition, many studies are ecological or retrospective and cannot completely exclude residual confounding. These limitations underscore the need for prospective cohorts, wearable sensors, repeated physiological measurements, and intervention studies.

Research priorities should focus on prospective studies in tropical and low- and middle-income countries that use personal or microenvironmental heat measurements, as well as the validation of locally appropriate pregnancy-specific heat thresholds and heat-health warning indicators. Further research is needed to examine occupational heat exposure among pregnant workers in agriculture, health care, food services, factories, markets, and informal employment. Studies should also integrate placental biomarkers, maternal cardiovascular measures, fetal monitoring, hydration status, and environmental exposure data to better understand the effects of heat exposure during pregnancy. In addition, intervention trials are needed to evaluate the effectiveness of cooling strategies, hydration, modified work schedules, community outreach, and heat-alert systems. Finally, equity-focused research should examine the influence of housing conditions, income, urban heat islands, electricity access, social protection, and barriers to antenatal care on maternal and fetal health outcomes.

CONCLUSIONS

Climate change is increasing exposure to extreme heat during pregnancy, and the evidence base now supports heat as an important maternal and perinatal health risk. The association with preterm birth is the most consistent, while evidence also implicates stillbirth, impaired fetal growth, gestational diabetes, hypertensive disorders, placental complications, and other adverse outcomes. Biological pathways involving thermoregulation, dehydration, cardiovascular strain, uteroplacental perfusion, inflammation, oxidative stress, and placental dysfunction provide plausible mechanisms. Because exposure and adaptive capacity are socially patterned, prevention must extend beyond individual advice. Maternal-health programs should incorporate heat-risk communication, occupational protection, community outreach, early warning systems, climate-resilient maternity services, and integrated climate-health surveillance. For tropical and resource-constrained settings, locally generated evidence is essential to identify actionable heat thresholds and effective interventions without assuming that risk estimates from temperate high-income countries apply unchanged.

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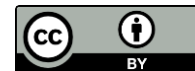


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