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Assessing Impact of Heat Waves on Pregnancy and Lactation Amidst Climate Change: A Scoping Review.

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ABSTRACT

Background:
The escalation of heat waves, attributed to climate change, represents a global public health concern, with pregnant and lactating women identified as particularly vulnerable due to Physiological and hormonal changes.

Aim:
To review the existing research on the effects of heat waves on pregnancy and lactation, identifying potential health risks and outcomes.

Methods:
A structured search across PubMed, Scopus, Web of Science, and Google Scholar was conducted using terms related to heat waves, pregnancy, lactation, and climate change**.** Inclusion criteria focused on peer-reviewed empirical studies in English.

Results:
Heat waves are linked to increased risks of preterm labor, low birth weight, gestational hypertension, and preeclampsia in pregnant women, and reduced milk production and altered composition in lactating women. Vulnerable groups, especially in low-income and heat-prone regions, are disproportionately affected.

Conclusion:
Heat waves pose significant risks to pregnant and lactating women, necessitating urgent public health interventions and policies. Future research should explore long-term effects and effective mitigation strategies.

Keywords: Heat Waves, Pregnancy, Lactation Amidst, Climate Change
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Introduction

The increasing frequency and intensity of heat waves, driven by climate change, pose a significant and escalating threat to public health worldwide. Among the vulnerable populations affected, pregnant and lactating women face unique and profound risks. As global temperatures continue to rise, understanding the specific impacts on this demographic becomes crucial for developing effective public health strategies and interventions.

Pregnant and lactating women are particularly vulnerable to heat waves due to several physiological and socio-economic factors. During pregnancy, women experience increased metabolic rates and cardiovascular demands, which can exacerbate the effects of high temperatures. Additionally, dehydration and heat stress can negatively impact both maternal and fetal health, leading to complications such as preterm birth, low birth weight, and stillbirth. Lactating women, on the other hand, require adequate hydration to maintain milk production, and heat stress can impair this critical function, affecting both the mother's and the infant's well-being. Furthermore, socio-economic factors such as limited access to air conditioning,

healthcare, and supportive services can amplify these risks, particularly in low-resource settings.

This scoping review aims to comprehensively examine the current body of research regarding the effects of heat waves on pregnancy and lactation outcomes. By synthesizing evidence from diverse studies, this review seeks to highlight the specific risks and adverse outcomes associated with heat waves for pregnant and lactating women as well as to shed light on the need for targeted public health strategies and interventions to safeguard pregnant and lactating women from the adverse effects of rising global temperatures. Through this review, we hope to inform policymakers, healthcare providers, and researchers about the critical areas that require attention and action to protect maternal and infant health in the face of climate change.

Climate change, in particular the exposure to heat, impacts human health and can trigger diseases. Pregnant people are considered a vulnerable group given the physiological changes during pregnancy and the potentially long-lasting consequences for the offspring. Evidence published to date on the higher risk of pregnancy complications upon heat stress exposure is from geographical areas with high ambient temperatures. Studies from geographic regions with temperate climates are sparse; however, these areas are critical since individuals may be less equipped to adapt to heat stress. (Yüzen et al., 2023)

There is growing evidence that pregnant women can appropriately thermo-regulate; however, when exposed to extreme heat, there are several processes that may occur, which could harm the mother or fetus, including a reduction in placental blood flow, dehydration, and an inflammatory response that may trigger preterm birth. (Samuels et al., 2022)

Preterm birth is a leading cause of infant morbidity and mortality. Identifying potentially modifiable triggers toward the end of gestation, such as extreme heat, can improve understanding of the role of acute stress on early deliveries and inform warning systems. (Ilango et al., 2020)

High ambient temperature was significantly associated with preterm birth for all mothers, regardless of maternal racial/ethnic group, maternal age, maternal education, or sex of the infant. Results indicated that an 8.6% increase (95% confidence interval: 6.0, 11.3) in preterm delivery was associated with a 10°F (5.6°C) increase in weekly average (lag06) apparent temperature. Greater associations were observed for younger mothers, blacks, and Asians. (Basu, Malig, & Ostro, 2010)

Preterm birth is an increasingly common and debilitating condition that affects a substantial portion of infants. Rates appear to be linked to high environmental temperature, and more especially heat stress, which may be experienced during extreme heat or following a sudden temperature rise. When this happens, the body may be unable to adapt quickly to the change. As global warming continues, the incidence of high environmental temperatures and dramatic temperature changes is also increasing. (Carolan-Olah & Frankowska, 2014)

Heat exposures are common, and the outcomes are important determinants of population health. Linkages between socioeconomic status and study outcomes suggest that risks might be largest in low and middle-income countries. Rising temperatures due to global warming could have major implications for child health. (Chersich et al., 2020)

There is evidence that temperature extremes adversely impact birth outcomes, including, but not limited to, changes in length of gestation, birth weight, stillbirth, and neonatal stress in unusually hot temperature exposures. (Kuehn & McCormick, 2017)

Even within the United States, where there is widespread access to air conditioning, heat waves increase the fraction of babies with abnormal conditions related to maternal stress, as well as the fraction of mothers who experience pregnancy-related adverse health conditions. The scope for these risks in developing countries is likely to be even greater.(Cil & Cameron, 2017)

Rates of preterm birth in developed countries were highest twice a year (once in winter and again in summer). In London (SMMIS data set), however, preterm births peaked only once a year, in winter. Babies born in winter were 10% more likely to be preterm compared with those born in spring (OR 1.10, 95% CI 1.07–1.14). (Lee, Steer, & Filippi, 2006)

Exposure to heat waves in the perinatal period may pose a threat to children's health. Pediatric diseases or conditions associated with heat waves include renal disease, respiratory disease, electrolyte imbalance, and fever. (Xu et al., 2014)

High ambient temperature is perceived by community members to have direct and indirect health pathways in pregnancy and postpartum periods, including on the neonates. The direct impacts include injuries on the neonate's skin and in the mouth, leading to discomfort and affecting breastfeeding and sleeping. Participants described babies as "having no peace". Heat effects were perceived to be amplified by indoor air pollution and heat from indoor cooking fires. Community members believed that exclusive breastfeeding was not practical in conditions of extreme heat because it lowered breast milk production. (Lusambili et al., 2024)

The incidence of preeclampsia in at least one pregnancy was 7% (2173/64,566); 2) during "warm" pregnancies, an elevation of one IQR of the average temperature in the 1st or the 3rd trimesters was associated with an increased risk to develop preeclampsia [patients with Jewish ethnicity: 1st trimester: relative risk (RR) of 2.38(95%CI 1.50; 3.80), 3rd trimester 1.94(95%CI 1.34;2.81); Bedouins: 1st trimester: RR = 2.91(95%CI

1.98;4.28), 3rd trimester: RR = 2.37(95%CI 1.75;3.20)]; 3) In "cold" pregnancies, an elevation of one IQR of average temperature was associated with a lower risk to develop preeclampsia among patients with Bedouin-Arab ethnicity RR = 0.68 (95% CI 0.49–0.94) for 1st trimester and RR = 0.62 (95% CI 0.44–0.87) for 3rd trimester. (Shashar et al., 2020)

Methodology

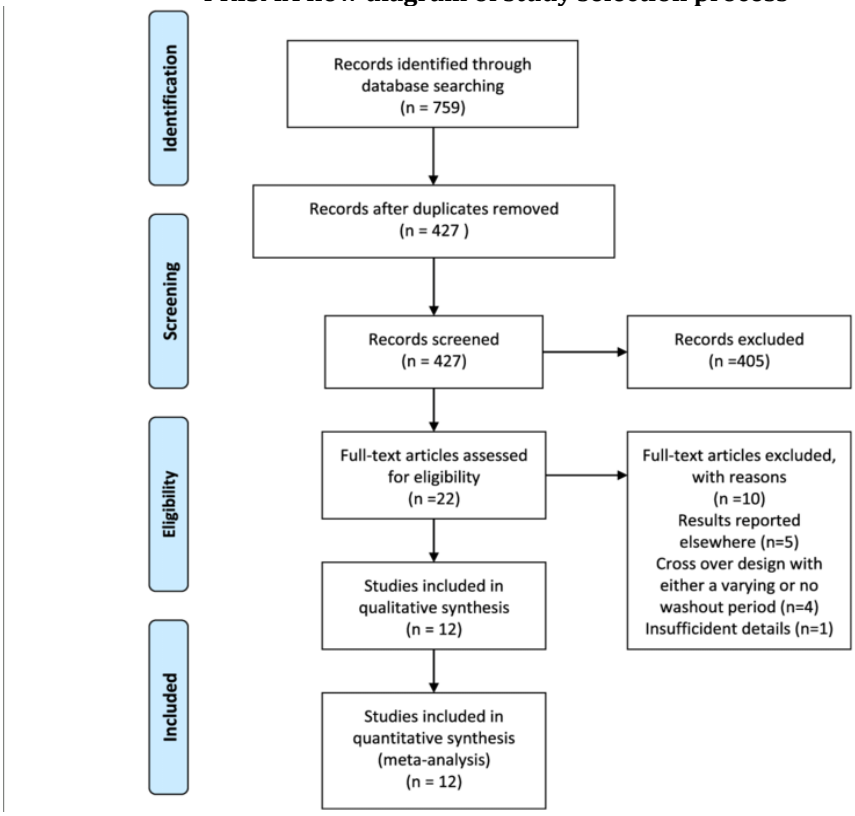
Search strategy

The methodology for this scoping review involved a structured search strategy to identify relevant studies and reports that investigate the impact of heat waves on pregnancy and lactation. The search was conducted across several academic databases, including PubMed, Scopus, Web of Science, and Google Scholar, to ensure comprehensive coverage of the literature. Key search terms included heat waves, pregnancy, lactation, maternal health, and climate change. These terms were used in various combinations and with Boolean operators to expand the search scope and retrieve a diverse range of studies.

To refine the search, specific phrases such as heat stress and pregnancy outcomes, thermal exposure and lactation, and climate change effects on maternal health were also employed. This approach facilitated the identification of studies that directly addressed the phenomena of interest.

Study selection process

PRISMA flow diagram of study selection process



The records identified from database searching were 759, duplicates 427, records screened 427, excluded 405, full text articles assessed 22, articles excluded with reasons 10, results reported elsewhere 5, crossover design with either varying or no washout period 4, insufficient details 1, studies included in synthesis 12, studies included in quantitative synthesis 12.

Inclusion criteria

The review included studies that met the following criteria;

Focus on the effects of heat waves or high temperatures on pregnant and lactating women.

Empirical research articles, including observational studies, longitudinal studies, and clinical trials

Peer-reviewed articles published in English.

Studies conducted on human subjects provide direct insights into the health impacts of heat exposure during pregnancy and lactation periods.

Exclusion criteria were;

Studies not specifically addressing the direct impacts of heat waves on pregnancy or lactation outcomes.

Articles that were not peer-reviewed, such as editorials, opinion pieces, and non-scientific reports.
Studies focusing on animal models, unless they provided significant insights applicable to human health contexts
Publications before 2000, unless they offered critical historical perspectives or foundational knowledge in the field

Time Frame and Geographical Focus;
The primary focus was on studies published from 2000 to the present, reflecting the most recent and relevant data in the context of current climate change trends. While the review was global in scope, particular attention was given to studies from regions highly susceptible to heat waves and where significant public health data were available, including but not limited to, subtropical and tropical areas, urban and densely populated regions, and areas with documented increases in temperature extremes due to climate change.
This methodology aimed to provide a robust framework for gathering and synthesizing the existing literature on the impacts of heat waves on pregnancy and lactation, thereby offering a comprehensive overview of the current state of knowledge in this critical area of public health research.

Results
The review revealed significant associations between heat waves and adverse pregnancy and lactation outcomes. Specifically, pregnant women exposed to heat waves faced increased risks of preterm labor, low birth weight, gestational hypertension, and preeclampsia. Similarly, lactating women experienced reduced milk production and alterations in milk composition under the influence of high temperatures. Furthermore, vulnerable populations, particularly women residing in low-income and heat-prone regions, bore disproportionate impacts from these heat-related health risks. The results from the reviewed studies are summarized in Table 1 (Appendix A)
A total of 12 studies were selected and analyzed to identify the impact of heat waves on pregnancy and lactation. The included studies represented most of the countries in the world: North America, 3; Oceania, 3; Europe, 1; Asia, 1; 4 studies didn't indicate the countries.

Impact of heat waves on pregnancy
The included studies had various significance of the impact of heat wave on pregnancy: 10 studies reported preterm labor, 6 studies reported low birth weight, 3 studies reported preeclampsia, 7 studies reported still birth, and 5 studies reported congenital anomalies.

Impact of Heat Waves on Lactation
Among the included studies, 3 reported reduced milk production, and 3 reported altered milk production.

Vulnerable Populations and Regional Disparities
All 12 studies considered women in low-income regions and high heat regions as the ones at greatest risk of experiencing serious impacts of heat waves during pregnancy and lactation.

Discussions
The analysis of 12 studies aimed at understanding the impact of heat waves on pregnancy and lactation provides a comprehensive overview of this global health issue. The studies included in this analysis represent a diverse geographical distribution, covering North America, Oceania, Europe, and Asia, with a few studies not specifying their locations. This geographical diversity allows for a broader understanding of how heat waves may affect pregnancy and lactation across different climates, healthcare systems, and socio-economic contexts. The studies from North America contribute valuable insights into how heat waves impact pregnancy and lactation in a region characterized by varying climates and advanced healthcare infrastructure. The findings from these studies are critical as they can inform public health strategies in other parts of the world with similar climates or healthcare systems. Studies from Oceania provide data from regions with unique environmental conditions, including high temperatures and humidity levels. The impact of these specific climatic conditions on pregnancy and lactation can offer insights into how similar conditions in other parts of the world might affect maternal and neonatal health. The single study from Europe highlights the need for more research in this region, especially considering the increasing frequency of heat waves due to climate change. European countries, with their diverse climates and varying levels of healthcare resources, could benefit from more focused research on this topic. The one study from Asia underscores the importance of understanding the impact of heat waves in densely populated and rapidly developing regions. Given Asia's vast and diverse climate, further research is needed to generalize the findings and develop targeted interventions for this region. The studies that did not specify their locations highlight a gap in the data's geographical context, which is essential for tailoring public health interventions. Future research should ensure that the geographical context is clearly indicated to enhance the applicability and relevance of the findings.
The results of the analysis highlight the significant impact of heat waves on pregnancy outcomes, as evidenced by the various adverse effects reported across multiple studies. Preterm labor was the most commonly reported outcome, cited in 10 studies. This high incidence suggests a strong relationship between heat exposure and premature birth. The physiological stress induced by elevated temperatures may trigger labor earlier than expected, potentially through mechanisms

such as dehydration, increased uterine activity, or inflammatory responses. Premature birth poses significant risks for neonatal morbidity and mortality. Six studies reported an association between heat waves and low birth weight (LBW). LBW is a critical indicator of neonatal health, linked to a range of short- and long-term complications, including developmental delays and chronic health conditions. The observed association may be attributed to heat-induced stress leading to reduced placental blood flow and impaired fetal growth. Pregnant women exposed to extreme heat may also experience reduced appetite and hydration, further impacting fetal development. Three studies highlighted a link between heat waves and preeclampsia, a condition characterized by high blood pressure and organ damage in pregnant women. Preeclampsia can have severe consequences for both the mother and the fetus, including the risk of eclampsia, preterm birth, and placental abruption. The exact pathophysiological mechanisms remain unclear, but it is hypothesized that heat-induced vascular stress and inflammation may contribute to the development of this condition. Seven studies reported an increase in stillbirths associated with heat waves. Stillbirth, defined as the death of a fetus at or after 20 weeks of gestation, is a devastating outcome with profound psychological and emotional impacts on families. The increased risk of stillbirth during heat waves may be related to maternal hyperthermia, leading to placental insufficiency and fetal hypoxia. Finally, five studies reported an association between heat exposure and congenital anomalies. These birth defects, which occur during fetal development, can have lifelong implications for affected individuals. The mechanisms by which heat waves may contribute to congenital anomalies are not fully understood, but may involve heat-induced teratogenic effects or disruptions in maternal-fetal homeostasis.

The analysis of the included studies reveals critical insights into the impact of heat waves on lactation, specifically focusing on milk production. Out of the 12 studies, six addressed issues related to milk production, with three reporting reduced milk production and three reporting altered milk composition. Reduced milk production can have severe implications for infant nutrition and health. Several factors may contribute to this phenomenon: Heat waves increase the risk of dehydration, which can impair a lactating mother's ability to produce sufficient milk. Dehydration can reduce blood volume and, consequently, the volume of milk produced. The physiological stress from extreme heat can disrupt hormonal balance, particularly prolactin and oxytocin, which are crucial for milk synthesis and ejection. Stress can inhibit the milk let-down reflex, further reducing milk production. High temperatures can suppress appetite and reduce the nutritional intake of lactating mothers, leading to decreased milk production. Ensuring adequate hydration and nutrition during heat waves is essential for maintaining milk supply. Another three studies reported alterations in milk composition during heat waves. Changes in milk composition can affect the nutritional quality of the milk and, consequently, the growth and development of the infant. The potential changes in milk composition due to heat exposure include: Extreme heat may alter the concentration of key nutrients in breast milk, including proteins, fats, and vitamins. These changes can impact the nutritional adequacy of the milk. Heat stress can affect the electrolyte balance in breast milk, potentially altering the levels of sodium, potassium, and chloride. These changes can influence the hydration status and electrolyte balance of the infant. Heat waves might affect the levels of immunological components such as antibodies and lactoferrin in breast milk. These components are crucial for the infant's immune protection and overall health. The reported reductions and alterations in milk production have direct implications for infant health; Insufficient milk production and altered milk composition can lead to nutritional deficiencies in infants, affecting their growth and development. Infants rely solely on breast milk for their nutritional needs, especially in the first six months of life. Changes in the immunological components of breast milk can make infants more susceptible to infections and illnesses. The protective effects of breastfeeding might be compromised during heat waves. Reduced milk production can lead to inadequate fluid intake for infants, increasing the risk of dehydration, especially during heat waves.

The analysis of the 12 studies identifies women in low-income regions and high-heat regions as the most vulnerable populations to the adverse impacts of heat waves during pregnancy and lactation. Women in low-income regions face multiple challenges that heighten their vulnerability to heat waves: Low-income regions often have inadequate healthcare infrastructure, reducing access to prenatal and postnatal care. This lack of access can delay the diagnosis and treatment of heat-related complications during pregnancy and lactation. Many women in low-income regions live in housing without adequate cooling facilities. Overcrowded living conditions and limited access to air conditioning can increase exposure to high indoor temperatures. Economic constraints can limit access to nutritious food and clean water. Nutritional deficiencies, combined with the increased metabolic demands of pregnancy and lactation, can exacerbate the health impacts of heat waves. Women in low-income regions are more likely to work in informal sectors, such as agriculture or manual labor, which involve outdoor activities and prolonged exposure to high temperatures. High-heat regions inherently pose greater risks during heat waves due to extreme environmental conditions: In regions with consistently high temperatures, pregnant and lactating

women are chronically exposed to heat, increasing the cumulative stress on their bodies. These regions are often on the frontline of climate change, experiencing more frequent and severe heat waves. The increasing intensity and duration of heat waves increase the health risks for vulnerable populations. High-heat regions frequently face water scarcity, making it difficult to maintain hydration, which is crucial during pregnancy and lactation. Limited water availability can also impact sanitation and hygiene, increasing the risk of infections. The combined socio-economic and environmental vulnerabilities significantly amplify the health risks for pregnant and lactating women in these regions: Pregnant women have higher metabolic rates and generate more body heat. Heat stress can lead to dehydration, preterm labor, and other complications. Lactating women also face challenges in maintaining hydration, affecting milk production and composition. The studies indicate that women in these regions are at greater risk of adverse pregnancy outcomes, including preterm labor, low birth weight, preeclampsia, and stillbirth. These outcomes are worsened by limited access to medical care and inadequate living conditions. Reduced and altered milk production due to heat stress can compromise infant nutrition, leading to poor growth and increased susceptibility to illness. The lack of support and resources for breastfeeding mothers in low-income regions further aggravates these challenges.

Limitation

Although the studies included cover regions such as North America, Oceania, Europe, and Asia, the representation is not comprehensive. Not all global regions, particularly those most affected by climate change, are adequately represented. The absence of studies from regions like Africa and parts of Latin America limits the generalizability of the findings.

The findings underscore the urgent need for public health interventions and policy measures to mitigate the risks posed by extreme heat events on vulnerable populations, particularly pregnant women.

Future research

Future research should ensure that the geographical context is clearly indicated to enhance the applicability and relevance of the findings.

More research is needed to understand the specific mechanisms by which heat waves affect milk production and composition. Studies should also explore effective interventions to support lactating mothers during extreme heat events.

Conclusion

The analysis of the 12 studies highlights significant concerns regarding the impact of heat waves on pregnancy and lactation, particularly for women in low-income and high-heat regions. The findings underscore the heightened risks of preterm labor, low birth weight, preeclampsia, stillbirth, congenital anomalies, reduced milk production, and altered milk composition. These adverse outcomes are exacerbated by limited access to healthcare, poor living conditions, and nutritional deficiencies prevalent in low-income areas.

Given the increasing frequency and intensity of heat waves due to climate change, it is crucial to prioritize targeted public health interventions, improve healthcare access, and develop effective cooling strategies to protect maternal and infant health. Addressing these challenges through comprehensive research, policy development, and community support can mitigate the detrimental effects of heat waves on vulnerable populations.

Healthcare providers should educate lactating mothers about the potential impacts of heat waves on breastfeeding and offer support to manage these challenges. This includes guiding the recognition of signs of dehydration and nutritional deficiencies in both mothers and infants.

Lactating mothers should be encouraged to maintain adequate hydration and nutritional intake during heat waves. Public health campaigns should emphasize the importance of drinking fluids and consuming nutrient-rich foods.

Providing access to cooling centers and air-conditioned environments can help reduce heat stress for lactating mothers, potentially mitigating the adverse effects on milk production and composition.

Emphasize the need for effective cooling strategies and timely medical interventions during heat waves.

Efforts should focus on enhancing surveillance, promoting public health education, and implementing sustainable climate adaptation strategies to safeguard the well-being of mothers and their children in the face of climate change.

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