Vulnerability Assessment and Empowering Solutions for Women's Health in the Face of Climate Change - Review Article

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Impact of ambient heat exposure on pregnancy outcomes in low- and middle-income countries: A systematic review

Sohail Lakhani[1,2], Sobia Ambreen[3], Zahra Ali Padhani[4,5], Yusra Fahim[6], Sana Qamar[7], Salima Meherali[8] and Zohra S Lassi[4,5]

Abstract

Increasing global temperatures due to climate change have raised serious concerns regarding its potential impact on health outcomes. Pregnant women and their fetuses are among the most vulnerable groups being affected by these dramatic changes resulting in adverse outcomes for both the mother and the developing fetus. Evidence regarding heat-related pregnancy adversities in high-income countries is conclusive, however, such evidence is rare in low- and middle-income countries (LMICs). This review was conducted to bridge the knowledge gap by providing evidence-based insights into the specific repercussions of high heat exposures during pregnancy and its effect on birth outcomes in LMICs. A systematic review was conducted to assess the impact of high environmental or ambient temperatures on pregnancy outcomes (abortion, stillbirth, preterm birth, and low birthweight (LBW)) in LMICs. Electronic searches were conducted on MEDLINE, Embase, CINAHL, Web of Science, and Scopus. Observational studies published between 2010 and 2023 were included in the review. Screening of studies was done using Covidence software, data was extracted on Excel sheets and quality assessment was done using the National Institutes of Health's National Heart, Lung, and Blood Institute tool. We included 11 studies. Four of six studies that included preterm births showed an association between heat and preterm births. Four of five studies reported an association between heat exposure and LBW. Three of four studies on stillbirths showed a significant association between heat exposure and stillbirths. One of the two studies that reported spontaneous abortion revealed a significant association of heat with abortion. Meta-analysis could not be performed due to the lack of homogeneity in defining heat exposure. Amongst the included studies, seven were categorized as "good" and four were categorized as "fair" on methodological quality. This study concluded that ambient temperature and heat exposure during pregnancy can impact birth outcomes such as preterm births, LBWs, abortions, and stillbirths in LMICs. Urgent action is imperative on both national and global scales to facilitate a comprehensive and definitive assessment of heat exposure in LMICs, enabling a deeper understanding of its repercussions on pregnant women. Longitudinal studies are paramount for confirming these associations and devising targeted interventions and strategies aimed at enhancing maternal and child health within LMIC contexts. Registration:
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Keywords

heat, ambient temperature, pregnancy outcomes, preterm births, stillbirths, abortion, low birth weight, low- and middle-income countries

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[1]Department of Community Health Sciences, Aga Khan University, Karachi, Pakistan
[2]School of Public Health, Texas A&M University, College Station, TX, USA
[3]Center for Healthcare and Communities, Coventry University, Coventry, UK
[4]Robinson Research Institute, Faculty of Health and Medical Sciences, University of Adelaide, Adelaide, SA, Australia
[5]School of Public Health, Faculty of Health and Medical Sciences, University of Adelaide, Adelaide, SA, Australia
[6]Institute for Global Health and Development, Aga Khan University, Karachi, Pakistan
[7]Department of Medicine, Aga Khan University, Karachi, Pakistan
[8]College of Health Sciences, Faculty of Nursing, University of Alberta, Edmonton, AB, Canada

Corresponding author:
Sohail Lakhani, Department of Community Health Sciences, Aga Khan University, National Stadium Road, Karachi 75700, Pakistan.
Emails: drsohailakhani@gmail.com; sohail.lakhani22@alumni.aku.edu

Introduction

In recent years, climate change has emerged as a complex global phenomenon, inducing substantial shifts in Earth's weather patterns. These alterations manifest in various environmental threats, notably rising temperatures and the occurrence of thermal waves.[1] From 1910 to 2007, the global average temperature has increased by 0.75°C.[2] Forecasts based on predictive models and ongoing trend observations indicate that the global average temperature is currently escalating at a rate between 0.15°C and 0.38°C per decade. This trajectory indicates a probable breach of the proposed safe threshold (<2°C increase in global average temperature compared to preindustrial levels) within this century.[2,3] This rise in global temperature has raised serious concerns regarding the potential health implications of extreme heat spells[4,5] including an increase in the risk of deaths, non-communicable diseases, the emergence and spread of infectious diseases, and other health crises such as heat cramps, collapse, and stroke.[1,4]

Certain demographic groups face disproportionate vulnerability to the detrimental consequences of extreme heat including individuals aged 65 or older, those with chronic illnesses, children,[6] outdoor workers, athletes, and individuals lacking stable housing.[7] Notably, pregnant women and their fetuses also represent a large group of a vulnerable population, highlighting the need to raise awareness about climate change, target attention in comprehensive health planning due to its potential and proven impact, develop evidence-based intervention strategies, and inform public health policies to minimize the effect of climate change on these groups of people.[8] The absence of universally standardized definitions and criteria for various heat conditions, including terms like excessive heat, extreme heat, heat waves, high ambient temperatures, and extreme heat events, poses a significant challenge in addressing the escalating global temperatures associated with climate change.[9] This lack of clarity hampers the thorough understanding and mitigation of potential health implications of extreme heat events.

Pregnant women due to the physiological changes in blood volume, circulation, and the change in hormonal system are more susceptible to external heat stressors and are unable to effectively regulate their body temperature which makes them more vulnerable to the adverse health effects of heat. Literature has shown a link between environmental heat stress and unfavorable pregnancy outcomes, attributed to the potential impairment of physiological adjustments critical for supporting fetal development, resulting in problems of thermoregulation and the hazards associated with heat stress.[10] Studies have shown that pregnant women when exposed to extreme heat face an elevated risk of experiencing life-threatening complications during childbirth. This heightened risk is further observed with an increased likelihood of preterm and early-term births. Moreover, maternal exposure to heat has been correlated with a higher incidence of high blood pressure, hypertensive disorders, and other adverse pregnancy outcomes.[11]

According to the recent systematic review and meta-analysis of 27 countries including low- and middle-income countries (LMICs), 40 out of 47 studies reported preterm births to be more common at higher temperatures. The odds of a preterm birth rose 1.05-fold per 1°C increase in temperature and 1.16-fold during heatwaves. Higher temperature was associated with reduced birth weight in 18 out of 28 studies, with considerable statistical heterogeneity. On the other hand, stillbirths increased 1.05 times per 1°C rise in temperature. The associations between temperature and adverse outcomes were largest among women in lower socioeconomic groups and at age extremes.[12] Another scoping review included a total of 75 studies conducted across 24 countries, primarily high-income countries (HICs), that concluded that pre-term birth was the most common adverse outcome associated with elevated ambient temperature exposure during pregnancy, followed by low birthweight (LBW), stillbirth, and gestational diabetes mellitus.[13] Similar studies conducted in South Africa and elsewhere have concluded that exposure to extreme heat during pregnancy and childbirth had negative effects on maternal health and birth outcomes, including complications such as pre-eclampsia and gestational diabetes, as well as an increased risk of LBW, preterm birth, and stillbirth.[14–16]

While existing research has explored the association between elevated temperatures and pregnancy outcomes particularly in HICs, a substantial gap remains in understanding the burden of health impact due to high temperatures relevant to LMICs as these regions have distinct socioeconomic and healthcare contexts compared to HICs significantly influencing maternal health. Exploring the possible role of heat events in the high maternal and neonatal morbidity rates in LMICs can provide important insights into existing and future research. Thus, this review aims to bridge the knowledge gap by providing evidence-based insights into the specific repercussions of high heat exposures during pregnancy and its effect on birth outcomes in LMICs.

Methods

This systematic review has been registered with the Prospective Register of Systematic Reviews (PROSPERO: CRD42023449173) which can be accessed online. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses in Supplemental Figure 1[17] and Conduct of Systematic Reviews in Toxicology and Environmental Health Research guidelines[18] for reporting our study findings.

Eligibility criteria

We included observational studies such as case–control studies, prospective and retrospective cohort studies, and cross-sectional studies involving all nulliparous and multiparous pregnant women from LMICs reporting on the impact of high environmental or ambient temperatures (exposure as defined by authors) only or compared to low or normal ambient temperatures on pregnant women. In studies where a lag period was mentioned, we included studies with a lag of 0 to observe the immediate effect of heat on pregnancy outcomes.

We also included gray literature including reports and dissertations; however, excluded commentaries, editorials, conference abstracts, systematic reviews, narrative reviews, randomized controlled trials, and quasi-experimental studies. Only studies that reported on adverse pregnancy outcomes, such as miscarriages/spontaneous abortions, stillbirths, LBW, small for gestational age (SGA), and preterm birth were included.

Search strategy

A search strategy was developed using the Medical Subject Headings and keywords such as "heat exposure," "pregnancy," "preterm," "abortion," "low birthweight," "stillbirths," "small for gestational age," and "adverse outcomes." The strategy was created by experts in the field (Z.A.P. and S.L.) with the help of senior authors and the librarian. Truncations and Boolean operators were used to devise a robust strategy that could retrieve all the relevant studies. Supplemental Appendix 1 shows database-specific strategies used for retrieval. Electronic searches were conducted on MEDLINE, Embase, CINAHL, Web of Science, and Scopus. Gray literature was searched on www.greynet.org and www.google.com (including Google Scholar). Reference lists of all the included studies and previously published systematic reviews were screened to identify studies that were found missing in the electronic search. We only included studies published in the English language between the years 2010 and 2023. Subscriptions to weekly updates and alerts for newly published studies were fully considered. The last date of the electronic search was September 18, 2023. We limited the timeframe to 2010–2023 because the prior proposed timeframe was very wide, and the results obtained were not streamlined. This may be due to methodological approaches in research which have evolved with time that the quality of studies has improvised and results getting more reliable and valid.

Study screening

All the studies identified through the electronic searches were imported on Covidence systematic review software,[19] for screening and de-duplicated. Three reviewers (S.A., S.Q. and Y.F.) independently screened the titles and abstracts for relevance. After title and abstract screening, all the included studies underwent full-text screening. Discrepancies at any stage of screening were resolved through discussion or by contacting senior authors (S.L. and Z.S.L.).

Data extraction and data synthesis

Data was extracted by two independent authors (S.A. and S.L.) on a standard Excel sheet. Discrepancies during the data extraction process were resolved through discussion or by contacting a third author (Z.A.P.). Authors were contacted in case of missing data. Data was extracted on study characteristics, study population, setting, exposure, comparison group, and outcomes of interest.

Two authors (S.A. and S.L.) independently assessed the quality of included studies which was verified by a third author (Z.S.L.). Disagreements were resolved through discussion. We used the National Institutes of Health's National Heart, Lung, and Blood Institute (NHLBI) tool (Supplemental Appendix 3)[20] to assess the methodological quality of the included studies based on 14 criteria. At the time of protocol development, another tool was chosen for the quality assessment but based on the robustness and reliability of the NHLBI tool for observational studies, it was deemed more appropriate by the panel of authors hence it was used. Studies were rated as "Good," "Fair," or "Poor" based on the degree to which they met the specific criteria.

Data analysis

We planned to conduct a meta-analysis on RevMan software 5.4, The Cochrane Collaboration, 2020, but we did not find data eligible for analysis due to variation in exposure assessment, therefore all the study findings were presented descriptively in the text. Dichotomous data was presented using odds ratios (ORs), relative risk (RR), hazard ratio (HR), and 95% confidence intervals (CIs) as reported by the authors. We also planned to conduct subgroup analysis for studies with high heterogeneity, but it was not possible due to the way exposure was reported in the study.

Results

Our search identified 7910 studies from 5 databases including PubMed ($n=7079$), CINAHIL ($n=725$), Embase ($n=75$), Web of Science ($n=6$), and Scopus ($n=25$). After removing duplicates ($n=97$), the studies were screened by title and abstracts ($n=7813$). The retrieved studies ($n=16$) were then assessed for eligibility via full-text screening resulting in the exclusion of five studies. The final studies included in the review summed up to 11 as shown in Supplemental Appendix 2.

Characteristics of included studies

The included studies covered data from 31 countries over the publication period of 2016–2023. These included LMICs in Asia (including China, Pakistan, India, Vietnam, and Iran) and Africa (survey data on 15 Sub-Saharan African countries, Ghana, and a Demographic Health

Table 1. Association of heat exposure to preterm birth.

Study ID	Sample size	Exposure	Measures of association
He et al.[21]	838,146	99th Percentile in the last 4 weeks	HR: 10.0% (2.9%–17.6%)
Shankar et al.[24]	126,273	Risk of 5° increase in the second trimester	RR: 1.05 (1.02–1.07)
		Risk of 5° increase in the first trimester	RR: 1.04 (1.01–1.06)
Wu et al.[28]	11,056	Average diurnal temperature range	OR: 1.05 (1.05–1.10)
Guo et al.[22]	1,040,638	>95th Percentile during preconception	OR: 1.22 (1.16–1.29)
		>95th Percentile during weeks 1–7 of gestation	OR: 1.11 (1.05–1.17)
		>95th Percentile during weeks 8–14 of gestation	OR: 1.15 (1.09–1.21)
		>95th Percentile during weeks 15–21 of gestation	OR: 1.11 (1.04–1.16)
		>95th Percentile 4 weeks before delivery	OR: 1.05 (0.99–1.11)
Liang et al.[27]	58,411	Cumulative effects (up to 30 days) of high temperature (95th and 99th percentiles)	RR: 0.69 (0.60–0.80)
Khodadadi et al.[31]	150,766	Cumulative RRs in high UTCI	RR: 1.10 (0.71–1.71)

HR, hazard ratio; RR, relative risk; OR, odds ratio; UTCI, Universal Thermal Climate Index.

Survey (DHS) dataset analysis of 37 African countries). By design, most of the studies ($n=6$) were time series followed by retrospective cohort design ($n=2$), time-stratified case-crossover ($n=2$), and within space–time series ($n=1$).

The studies were categorized based on the pregnancy outcomes that included preterm births ($n=6$), stillbirths ($n=4$), birth weight and LBW ($n=5$), and spontaneous abortion ($n=2$). The studies were further categorized based on the exposure variable, which considered the wide range of definitions and variables for ambient outdoor temperature; these included absolute temperatures (such as mean temperature in two studies,[21,22] average minimum, or maximum temperatures in two studies,[23,24] temperature variability (TV), which referred to metrics of quantified relative temperature (such as inter-day or intra-day variation) in one study,[25] departure from average in one study,[26] low and high temperatures in terms of percentiles in one study,[27] diurnal temperature range as a difference between high and low temperature in one study,[28] and heatwaves and extreme temperatures with temperatures exceeding certain high temperatures in one study.[29] Two of the studies included utilized Universal Thermal Climate Index (UTCI) as exposure.[30,31] Therefore, the exposure measurement was difficult due to the extreme variability in each study's exposure measurement.

Quality appraisal results

We used the National Institutes of Health's (NHLBI) tool for observational and cross-sectional studies to assess the quality of included articles. This is a tool that consists of 14 questions to assess the internal validity of a study. Two reviewers individually respond to each 14 questions and an outcome is decided regarding the quality of the article according to the responses. Out of 11 articles, 7 articles were rated "good"[21–23,25–27,30] and 4 articles were rated "fair."[24,28,29,31] Detailed quality assessment is attached in the Supplemental Appendix 3. Amongst the 11 studies included in the review, 7 studies fulfilled the criteria of the checklist as applicable hence they were categorized as good studies. The remaining four studies fulfilled approximately 90% of the criteria; hence, they were categorized as fair studies.

Heat and preterm birth. Table 1 describes the characteristics of the included studies that determined an association between heat/ambient temperature with preterm birth. Amongst the six studies, four were conducted in China, one in India and Pakistan, and one in Iran. Study sample sizes ranged from 11,056[28] to 1,040,068.[22]

A study conducted in 132 cities in China ($n=1{,}040{,}638$) considered heat exposure as temperature >95th percentile and reported a 7.2% preterm rate in this study.[22] Heat exposure was assessed in various ways including exposure throughout pregnancy as well as 3 months before pregnancy. The study found a significant association between heat and preterm birth, especially in the preconception period (3 months before pregnancy; OR = 1.22 (95% CI: 1.16–1.29)).[22]

Similarly, results from a 2-year birth cohort of Wuhan, China ($n=11{,}056$) reported a significant association between average diurnal temperature range and preterm birth especially the 2 weeks before delivery (OR = 1.05 (95% CI: 1.05–1.104)).[28] Another study from Guangzhou, China ($n=838{,}146$) assessed heat exposure as the average temperature during each week of gestation over 10 years. Heat exposure was divided into four windows including 1 week before delivery, 4 weeks before delivery, 20 weeks onwards, and entire pregnancy. In this study, extreme heat was (31.9°C or more than 99th percentile) associated with a 10% increased risk of preterm birth (HR = 10% (95% CI: 2.9%–17.6%)).[21] A retrospective study on global maternal health registry data from India and Pakistan ($n=126{,}273$) reported a significant association between greater temperatures in the second trimester with preterm birth in the overall cohort (RR = 1.05 (95% CI: 1.02–1.07)).[24]

Table 2. Association of heat exposure to stillbirths.

Study ID	Sample size	Exposure	RR
Shankar et al.[24]	126,273	Risk of 5°C increase in first trimester	1.02 (0.96–1.08)
		Risk of 5°C increase in the second trimester	1.06 (1.02–1.07)
		Risk of a 5°C increase in the third trimester	1.07 (0.99–1.15)
Nyadanu et al.[30]	5,961,328	Universal Thermal Climate Index (UTCI)	1.18 (1.02–1.36)
Khodadadi et al.[31]	150,766	Cumulative RRs in high UTCI	2.04 (1.01–4.15)
Davenport et al.[29]	65,328	Third-trimester heat exposure	0.04 (0.01–0.08)

RR, relative risk; UTCI, Universal Thermal Climate Index.

Table 3. (a) Association of heat exposure to birthweight.

Study ID	Sample size	Exposure	Beta coefficient
Davenport et al.[29]	65,328	First trimester exposure to hot days	−0.12 (−0.2, −0.04)
		95°F–99°F	−0.18 ($p<0.01$)
		100°F–104°F	−0.25 ($p=0.018$)
		104°F+	−0.44 ($p<0.01$)
Le et al.[26]	1961	One standard deviation rise in temperature relative to the local normal temperature in the first trimester	−0.06 (SE: 0.02)

(b) Association of heat exposure to low birthweight.

Study ID	Sample size	Exposure	Measures of association
Shankar et al.[24]	126,273	Risk of 5°C increase in first trimester	RR: 1.02 (1.0–1.04)
		Risk of 5°C increase in second trimester	RR: 1.02 (1.01–1.04)
Wang et al.[25]	333,618	Temperature variation	OR: 7.3% (95% CI: 4.4%–10.3%)
Khodadadi et al.[31]	150,766	Cumulative RRs in high UTCI	RR: 0.66 (0.21–2.09)

RR, relative risk; OR, odds ratio; UTCI, Universal Thermal Climate Index.

Another study assessed heat exposure as a high UTCI over 10 years in Iran ($n=150,766$) and reported no significant association between high UTCI and preterm labor (RR = 1.10 (95% CI: 0.71–1.71)).[31] However, another study in Shenzhen, China by Liang et al. ($n=58,411$) found a protective association between ambient high temperature with preterm birth. The cumulative effects (up to 30 days) of high temperature (95th and 99th percentile) on preterm birth were (RR = 0.69 (95% CI: 0.60–0.80)) and (RR = 0.62 (95% CI: 0.52–0.74)).[27]

Heat and stillbirths. Four studies assessed the relationship between ambient heat and stillbirths (Table 2). A study conducted in Iran concluded a significant positive relationship between high UTCI and stillbirths (RR = 2.04 (95% CI: 1.01–4.15)).[31] Another study that assessed heat stress using monthly district-level UTCI over a period of 8 years in 260 local districts of Ghana ($n=5,961,328$) reported a significant association of heat exposure with stillbirths (RR = 1.18 (95% CI: 1.02–1.36)).[30] The retrospective study conducted in India and Pakistan did not show any significant change in the rates of stillbirths in any of the trimesters. The results were assessed in terms of a 5°C increase in average daily maximum temperature for each of the trimesters. In the second and third trimesters, RRs of stillbirth were (RR = 1.06 (95% CI: 1.02–1.07, $p=0.07$)) and (RR = 1.07 (95% CI: 0.99–1.15, $p=0.07$)) respectively.[24] Davenport et al.'s study in the Sub-Saharan African region ($n=65,328$) also reported a significant association between hot exposure with stillbirth in the third trimesters (Coefficient = 0.04 (0.01–0.08)).[29]

Heat and birthweight/LBW. Association of birthweight with heat exposure was assessed in five studies (Table 3a and 3b). A study conducted in India and Pakistan found a significant positive association between greater heat exposure with LBW in both the first (RR = 1.02 (95% CI: 1.0–1.04)) and second trimesters (RR = 1.02 (95% CI: 1.01–1.04)) in the full cohort.[24] A study that pooled data from 37 countries of Africa ($n=333,618$) included in the DHS survey from a period of 1990–2020, reported that an extremely high overall TV (97.5th percentile) over the entire pregnancy period increased the odds of LBW by 7.3%. (OR = 7.3% (95% CI: 4.4%–10.3%)). LBW was defined as birthweight less than 2500 g and birthweight greater and equal to 2500 g was taken as a reference.[25] Another study

Table 4. Association of heat exposure to spontaneous abortion.

Study ID	Sample size	Exposure	Measures of association
Khodadadi et al.[31]	150,766	Cumulative RRs in high UTCI	RR: 1.02 (0.58–1.78)
Davenport et al.[29]	65,328	First trimester heat exposure	Coefficient: 0.10 (0.05–0.17)

RR, relative risk; UTCI, Universal Thermal Climate Index.

from Sub-Saharan Africa assessed the impact of exposure to hot days on the probability of healthy birthweight birth. They found that when the temperature on hot days was between 95°F and 99°F, the likelihood of a healthy birthweight was decreased by 1.9%, between 100°F and 104°F, it decreased by 2.5% and above 104°F, it decreased by 4.4%. They also noted that exposure to hot days during the first trimester decreases the probability of healthy birthweight in first trimester significantly (coefficient = −0.12 (95% CI: −0.2, −0.04)).[29] Another study in Vietnam (n = 1961) showed that one standard deviation rise in temperature relative to the local norm (approximately 0.52°C) during the first trimester of pregnancy reduced the child's weight at birth by 67 g (beta coefficient = −0.06 (SE: 0.02)).[26] However, the study from Iran did not find a significant association between high UTCI and LBW (RR = 0.66 (95% CI: 0.21–2.09)).[31]

Heat and spontaneous abortion. Spontaneous abortion was reported in two studies (Table 4). A study from Sub-Saharan Africa reported that exposure to hot days during the first trimester can significantly increase the probability of early pregnancy loss (coefficient = 0.10 (95% CI: 0.05–0.17)).[29] The study by from Iran also assessed the association of cumulative RRs in high UTCI with spontaneous abortion, however, did not find any significant association (RR = 1.02 (95% CI: 0.58–1.78)).[31]

Discussion

Our review highlights the vulnerability of pregnant women to environmental challenges in general and climate change in particular. The findings of our systematic review validate our hypothesis that ambient heat is associated with pregnancy adversities including preterm births, LBW, and stillbirths in LMICs which are already highly vulnerable to these adverse outcomes. Even though the estimates obtained are extremely diverse, negative and even statistically insignificant in some studies due to variations in the exposure assessment, the direction predominantly remains constant thus concluding a positive association amongst them. The UTCI which has been used excessively in assessing climate related impact on the health of humans[32] has also shown an association with the adversity of pregnancies in several populations.[30]

Our review depicts that the estimates were more pronounced in the second trimester of pregnancy as opposed to the first and third trimesters according to two studies.[22,24] This aligns with the fact that any unfavorable exposure during this period can lead to problems in the growth of the fetus and eventual birth defects.[33] The common adverse effects observed during the second trimester include low levels of amniotic fluid, preterm deliveries, and termination of pregnancies.[34] Nevertheless, the heat related risk of preterm and other outcomes exists throughout pregnancy as also concluded in a study conducted in Australia.[35]

Animal studies have shown that heat stress causes reduction in the blood flow of the placenta thus resulting in deprivation of nutrients and oxygen supply to the fetus.[36,37] Prolonged presence of heat stress in late pregnancy has been shown to lead to reduced size of the placenta and eventual fetal growth restriction, SGA, preterm birth, or stillbirth. Concurrently, cyclic heat stress during early pregnancy may lead to alterations in the expression of genes responsible for coding metabolic and transport proteins carrying peptides and glucose.[38] These mechanisms eventually lead to a reduction in placental flow and eventual severe outcomes. Moreover, there is still a lack of robust evidence relevant to human populations to understand the pathophysiological pathways of heat stress and human health.

The relationship observed between adverse outcomes and ambient heat is much stronger in LMICs as compared to HICs.[12] Studies have shown a 1.05 folds increase in the risk of stillbirths (95% CI 1.03–1.07) in HICs, whereas studies of LMICs have shown a 1.18 fold (95% CI: 1.02–1.36)[30] to 2.04 (95% CI: 1.01–4.15) risk in LMICs.[31] This high magnitude may be attributed to the social vulnerability of women in low-income settings where women are responsible for performing household chores that include cooking, fetching water, and assisting their families in farming.[12] In agricultural and other outdoor jobs, exposure to high temperatures may happen even before a pregnancy is detected. Even in the latter stages of pregnancy, less fortunate women may work above their heat tolerance thresholds to keep their jobs intact.[39] Given that the burden of maternal and neonatal mortality is the highest in the LMICs,[40] it seems extremely important to work toward the reduction of the additional burden posed by environmental factors and find sustainable solutions to this added risk of maternal adversities.

The strength of our review is in the fact that it is the first review that focuses primarily on LMICs. The heightened vulnerability of women in low-income settings makes them more prone to factors that are dealt with easily in high-income populations; hence, evidence for interventions and policies for these regions is needed accordingly. Our review also highlights the scarcity of robust evidence in this research area in the LMICs where it is of utmost significance suggesting that more studies are needed to understand the impact of heat in these vulnerabilities. On the other hand, our inability to meta-analyze the results was our primary limitation. The differences in exposure assessment, outcome definition, and estimates reporting were among the primary reasons why meta-analyses could not be performed. Due to limited standardization, the results were presented as they were reported. Furthermore, the restriction to English language publications may have led to the exclusion of some relevant studies. At the same time, the quality of studies remains relatively fair and few good quality studies are available in LMICs hence compromising the validity of results.

The implications of this review in terms of research include investigating the molecular and cellular mechanisms underlying the relationship between high temperatures and adverse pregnancy outcomes and exploring how heat stress affects key physiological processes during pregnancy. It also calls for conducting long term, prospective studies to track the impact of chronic exposure to high temperatures on maternal health and fetal development which will provide insights into cumulative effects over time. At the same time, it calls for including diverse populations in terms of ethnicity, socioeconomic status, and geographical locations to understand their susceptibility and inform targeted interventions for at-risk groups. It also suggests integrating environmental data, such as temperature variations and heat waves, into pregnancy outcome studies as this can enhance the understanding of the temporal and spatial aspects of heat stress on reproductive health. At the same time, identify reliable biomarkers that indicate susceptibility to heat-related pregnancy complications. This can aid in early detection and intervention, improving maternal and fetal health outcomes.

In terms of practice, the review suggests the development of guidelines for healthcare providers to offer heat-resilient maternity care. This may include monitoring pregnant individuals during heat waves, providing cooling measures, and adjusting prenatal care plans accordingly. Additionally, implement educational programs for pregnant individuals on the risks associated with high temperatures and the importance of heat stress mitigation strategies and enhance awareness about the potential impact of climate change on reproductive health. It also calls for integrating discussions about environmental factors, including heat stress, into preconception counseling sessions. This will empower individuals with information to make informed decisions about family planning in consideration of environmental risks. It also supports the idea of collaboration with urban planners to design heat-resilient urban environments with consideration given to green spaces, shade provision, and climate-sensitive infrastructure to mitigate the impact of high temperatures on pregnant individuals. Not to forget to advocate for policies that address the intersection of climate change and reproductive health. This includes supporting initiatives to reduce overall environmental heat and implementing workplace policies to protect pregnant individuals from excessive heat exposure. Lastly, to encourage workplace adaptations to protect pregnant employees from heat stress, especially in industries with higher temperature exposure by implementing policies that allow for breaks, hydration, and alternative work arrangements during extreme heat events.

Conclusion

Our study highlights the heightened risk of pregnancy adversities in LMICs due to ambient heat and rising temperatures due to climate change. It calls for urgent attention both regionally and globally by relevant stakeholders to understand the unforeseen burden that can affect populations massively. It is highly recommended that longitudinal studies be conducted to further confirm these associations and that targeted interventions and strategies be devised aimed at enhancing maternal and child health within LMIC contexts.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Author contribution(s)

Sohail Lakhani: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Validation; Writing—original draft; Writing—review & editing.
Sobia Ambreen: Data curation; Formal analysis; Investigation; Methodology; Writing—original draft; Writing—review & editing.
Zahra Ali Padhani: Formal analysis; Methodology; Writing—original draft.
Yusra Fahim: Conceptualization; Data curation; Writing—original draft.
Sana Qamar: Data curation; Writing—original draft.
Salima Meherali: Investigation; Writing—review & editing.
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ORCID iDs

Sohail Lakhani https://orcid.org/0000-0003-3804-1978

Sana Qamar https://orcid.org/0009-0004-4234-8053

Supplemental material

Supplemental material for this article is available online.

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