JOURNAL OF MULTIDISCIPLINARY RESEARCH AND INTEGRATED SCIENCES

Volume 4, Issue 1, 2024 | **Article ID:** JMRIS-2024-004 | **Pages:** 46-57 | **Article Type:** Systematic Review
Received: 05-02-2024 | **Revised:** 22-02-2024 | **Accepted:** 01-03-2024 | **Published:** 15-03-2024

Urban Heat Exposure and Adverse Pregnancy Outcomes in Low- and Middle-Income Countries: A Systematic Evidence Synthesis

Samuel K. Mensah1*

1 School of Public Health, University of Ghana, Accra, Ghana

***Corresponding author:** Samuel Mensah School of Public Health, University of Ghana, Accra, Ghana | Sam12415@gmail.com

ABSTRACT

Background: Rising ambient temperatures and more frequent heat waves may increase pregnancy risk, particularly in low- and middle-income countries (LMICs) where baseline rates of preterm birth, stillbirth, low birth weight, outdoor work, poor housing, limited cooling, and constrained maternity services can coincide. Although urban heat islands are an important exposure pathway, pre-2024 LMIC evidence also demonstrates substantial rural and occupational vulnerability. **Objective:** To synthesize Q1 evidence available through 31 December 2023 on heat exposure and adverse pregnancy outcomes in LMICs, with emphasis on preterm birth, stillbirth, low birth weight, hypertensive disorders, fetal strain, urban-rural differences, and susceptibility windows. **Methods:** A structured systematic evidence synthesis was conducted using Q1 studies in obstetrics, environmental health, planetary health, and general medicine. Direct LMIC cohort, case-crossover, time-series, and physiological studies were prioritized, supported by high-quality systematic reviews. A new pooled effect estimate was not calculated because exposure metrics, temperature contrasts, lag periods, and outcomes differed substantially. **Results:** The 2020 BMJ meta-analysis found 5% higher odds of preterm birth per 1°C increase in temperature and 16% higher odds during heat waves; all eight stillbirth studies showed harmful associations, with an approximately 5% increase per 1°C. A 2022 analysis across 14 LMICs linked acute late-pregnancy heat with both preterm birth and stillbirth. In 126,273 pregnancies from India and Pakistan, second-trimester temperature was associated with preterm birth (RR 1.05, 95% CI 1.02–1.07) and low birth weight (RR 1.02, 95% CI 1.01–1.04), while third-trimester temperature was associated with gestational hypertensive disease (RR 1.07, 95% CI 1.02–1.12). Ghanaian national data showed up to 18% higher stillbirth risk at higher-moderate long-term thermal stress, and Chinese national data showed increased preterm-birth risk after compound and daytime-only heat waves, particularly among rural women. A field study in The Gambia demonstrated acute maternal heat strain and fetal strain during real-world heat exposure. **Conclusion:** Heat exposure is a credible and increasingly important risk factor for adverse pregnancy outcomes in LMICs. Risk is shaped not only by ambient temperature but by timing, duration, nighttime recovery, occupation, housing, access to cooling and water, nutrition, rurality, and health-system resilience. Adaptation strategies should therefore combine heat-warning systems, occupational protection, maternity counseling, cooling and hydration access, and locally validated temperature thresholds.

Keywords: heat exposure; pregnancy; preterm birth; stillbirth; low birth weight; climate change; low- and middle-income countries; urban heat; maternal health

1. Introduction

Extreme heat is becoming a major health hazard as climate change increases the frequency, intensity, and duration of hot-weather events. The health burden of heat is determined not only by ambient temperature but also by humidity, solar radiation, nighttime cooling, physical exertion, housing, access to water, cooling technologies, and underlying physiological vulnerability [1]. Pregnancy is a physiologically demanding state in which maternal cardiovascular function, plasma volume, metabolism, and thermoregulation are already altered. These adaptations create plausible pathways through which environmental heat may affect both the pregnant individual and the developing fetus.

Pregnancy outcomes are especially important in LMICs because environmental exposure can coincide with high baseline rates of preterm birth and stillbirth, limited availability of air conditioning, informal or outdoor work, nutritional vulnerability, unreliable electricity, crowded housing, long travel times to antenatal care, and health systems operating with constrained resources. Urbanization adds additional complexity. Dense built environments can retain heat into the night, while informal settlements may have poor ventilation and roofing materials that amplify indoor temperatures. At the same time, rural women may experience greater occupational heat exposure, agricultural work, transport barriers, and lower access to cooling.

The 2020 systematic review and meta-analysis by Chersich et al. consolidated the early epidemiological evidence linking high temperatures with preterm birth, low birth weight, and stillbirth [2]. The review found that the odds of preterm birth increased by approximately 5% per 1°C rise in temperature and by 16% during heat waves. All eight included stillbirth studies showed harmful associations with high temperature, and effects were often most evident close to delivery. Importantly, the authors noted stronger associations among women with lower socioeconomic status, raising concern that the burden of climate-related reproductive risk could be concentrated in settings with the least capacity to adapt.

Subsequent LMIC studies strengthened the evidence base. McElroy et al. conducted the first multi-country analysis focused specifically on 14 lower-middle-income countries and found that higher maximum temperatures and reduced diurnal temperature range in the week before birth were associated with preterm birth and stillbirth [3]. Bonell et al. then provided direct physiological evidence from pregnant subsistence farmers in The Gambia, showing that real-world heat stress and maternal heat strain were associated with fetal strain [4]. In 2023, large studies in South Asia, Ghana, and China demonstrated associations between heat and preterm birth, low birth weight, hypertensive disease, and stillbirth [5–7].

The planned focus of this review is urban heat exposure, but the available LMIC evidence does not support restricting interpretation to city residents. Heat vulnerability crosses urban and rural settings, and several of the strongest pre-2024 studies found greater risk among rural or lower-resource populations. The present synthesis therefore examines urban heat within a broader ambient-heat framework and explicitly compares how built environment, occupation, socioeconomic position, and health-system access modify risk.

2. Methods

2.1 Review design and evidence cutoff

A structured systematic evidence synthesis was conducted using peer-reviewed literature published no later than 31 December 2023. The search framework combined terms relating to pregnancy, heat, temperature, heat waves, urban heat, preterm birth, stillbirth, low birth weight, fetal growth, hypertensive disorders, fetal strain, LMICs, Africa, South Asia, China, and climate vulnerability. References were restricted to Q1 journals in relevant categories and prioritized direct LMIC data.

2.2 Eligibility and synthesis strategy

Eligible evidence included systematic reviews, retrospective or prospective cohorts, case-crossover studies, time-series analyses, and physiological field studies. Studies were included when heat exposure was assessed using ambient temperature, maximum temperature, heat-wave definitions, wet-bulb globe temperature, universal thermal climate index, or another interpretable thermal exposure metric. A new meta-analysis was not performed because effect estimates differed in exposure scale, gestational window, comparator temperature, lag structure, study design, and outcome definition. Quantitative findings were therefore synthesized narratively and presented as published estimates.

The evidence eligibility framework is summarised in Table 1.

3. Results

3.1 Systematic-review evidence

Chersich et al. reviewed 70 studies from 27 countries and provided the strongest pre-2024 synthesis of temperature and pregnancy outcomes [2]. Forty of 47 studies assessing preterm birth reported higher risk at higher temperatures. Random-effects meta-analysis estimated an odds ratio of 1.05 per 1°C increase in temperature and an odds ratio of 1.16 during heat waves. Higher temperature was associated with reduced birth weight in 18 of 28 studies. All eight stillbirth studies identified harmful associations, with the pooled pattern corresponding to an approximately 5% increase in stillbirth risk per 1°C increase in temperature. Heterogeneity was substantial, reflecting differences in exposure definitions, climate, pregnancy stage, and study design.

The review is important for LMIC interpretation because associations were stronger among socially disadvantaged populations and because the baseline burden of adverse pregnancy outcomes is already high in many low-resource settings. However, most available studies at that time had been conducted in higher-income settings. Later work directly addressed this geographic imbalance.

Major pre-2024 Q1 studies directly relevant to LMIC heat and pregnancy outcomes are summarised in Table 2.

3.2 Multi-country LMIC evidence

McElroy et al. linked spatially and temporally resolved Demographic and Health Survey birth data with globally gridded meteorological observations across Angola, Benin, Burundi, Ethiopia, Haiti, Malawi, Nepal, Nigeria, the Philippines, South Africa, Tajikistan, Timor-Leste, Uganda, and Zimbabwe [3]. More than 103,000 births were evaluated, including approximately 5,900 preterm births and 1,200 stillbirths. Higher maximum temperatures and smaller diurnal temperature range during the week before birth were associated with increased risk of both outcomes.

This analysis is particularly relevant to heat adaptation because it demonstrates that risk is detectable even in settings where ground-monitor networks are sparse. It also highlights nighttime recovery as a potentially important feature: reduced diurnal temperature range can indicate persistently hot conditions in which maternal physiology has less opportunity to dissipate accumulated heat.

3.3 South Asian pregnancy outcomes

Shankar et al. analyzed 126,273 pregnancies enrolled between 2014 and 2020 in the Global Network Maternal Newborn Health Registry at two Indian sites and one Pakistani site [5]. Each pregnancy was linked with daily maximum temperature, and trimester-specific exposure was analyzed against preterm birth, stillbirth, low birth weight, and gestational hypertensive disease.

Across the combined cohort, higher second-trimester temperature was associated with preterm birth, with a relative risk of 1.05 (95% CI 1.02–1.07). The association was strongest in Nagpur, where the relative risk was 1.07 (95% CI 1.03–1.11). Higher second-trimester temperature was also associated with low birth weight in the overall cohort (RR 1.02, 95% CI 1.01–1.04), while site-specific associations were observed with first-trimester heat in Thatta and second-trimester heat in Nagpur. Third-trimester temperature was associated with gestational hypertensive disease across all sites (RR 1.07, 95% CI 1.02–1.12), rising to 1.13 (95% CI 1.05–1.23) in Nagpur.

The study is notable because it broadens the endpoint beyond preterm birth and stillbirth. It suggests that heat may influence multiple maternal-fetal pathways and that susceptibility windows differ according to outcome.

3.4 Stillbirth and long-term heat stress in Ghana

Nyadanu et al. linked monthly thermal exposure to 90,532 stillbirths among 5,961,328 births across all 260 districts of Ghana between 2012 and 2020 [6]. Exposure was characterized using the Universal Thermal Climate Index, which integrates thermal conditions more comprehensively than temperature alone. Higher-moderate heat stress at the 90th percentile was associated with stillbirth risk that increased with longer exposure, reaching an RR of 1.18 (95% CI 1.02–1.36) relative to median UTCI.

Assuming a causal relationship, the investigators estimated 19 excess stillbirths per 10,000 births after six months and 27 excess stillbirths per 10,000 births after nine months of exposure to the 90th-percentile thermal condition relative to the median. Rural districts characterized by lower population density and lower gross domestic product were more vulnerable than more urbanized districts. This finding is important for an urban-heat review because it shows that city residence should not be treated as a universal marker of greater exposure or risk.

3.5 Heat waves and urban-rural differences in China

Guo et al. evaluated 5,446,088 singleton pregnancies across 30 Chinese provinces using a national maternal surveillance system [7]. Exposure to compound heat waves during the final week before delivery was associated with adjusted odds ratios for preterm birth ranging from 1.02 to 1.04 across six heat-wave definitions. Daytime-only heat waves produced estimates from 1.03 to 1.04 under higher-threshold or longer-duration definitions.

The urban-rural analysis was particularly informative. Under selected daytime-only heat-wave definitions, rural mothers had adjusted odds ratios of 1.05 to 1.09, whereas the corresponding urban estimates were approximately null. The results indicate that built environment, occupation, cooling access, and socioeconomic context can modify the same meteorological exposure.

Selected pre-2024 published effect estimates relevant to heat and pregnancy outcomes are presented in Figure 1.

3.6 Physiological evidence from The Gambia

Epidemiological associations become more credible when linked to physiological observations. Bonell et al. studied pregnant subsistence farmers in West Kiang, The Gambia, during routine agricultural and manual activities [4]. Environmental heat was measured using wet-bulb globe temperature and UTCI, while maternal heat strain was estimated using heart rate and skin temperature. Fetal heart rate and umbilical artery resistance were assessed before and during work.

Pregnant women were frequently exposed to extreme heat stress during ordinary work, and both environmental heat stress and maternal heat strain were associated with fetal strain. The study provides a mechanistic bridge between ambient exposure and adverse pregnancy outcomes by showing that heat can produce measurable fetal physiological effects before delivery. It also demonstrates why occupational exposure must be considered alongside residential urban heat.

Outcome-specific interpretation of the pre-2024 evidence is summarised in Table 3.

3.7 Biological and contextual pathways

Heat can increase maternal peripheral blood flow as the body attempts to dissipate thermal load. In pregnancy, this response may compete with uteroplacental perfusion, particularly during dehydration or exertion. Maternal dehydration can alter plasma volume and cardiovascular demand, while thermal stress can activate inflammatory, endocrine, and uterine pathways. The Gambian field study directly demonstrated changes compatible with fetal strain, and experimental-clinical work has reported altered uterine blood flow under heat stress [4,8].

These biological pathways operate within social environments. Urban heat islands can elevate nighttime temperatures, poorly ventilated housing can maintain indoor heat after sunset, and electricity costs or outages can make mechanical cooling inaccessible. Rural and peri-urban women may face additional occupational exposure through farming, market work, domestic labor, water collection, or long travel to healthcare facilities. Malnutrition, anemia, hypertension, limited antenatal care, and lack of safe drinking water may further reduce physiological resilience.

Biological and contextual pathways linking heat exposure with adverse pregnancy outcomes are presented in Figure 2.

3.8 Implications for heat adaptation

The evidence does not support a single universal temperature threshold for pregnancy risk. Absolute temperature, local acclimatization, humidity, duration, nighttime temperature, gestational stage, activity level, and socioeconomic conditions all influence risk. Heat-warning systems should therefore be locally calibrated and should identify pregnant women as a priority group rather than relying solely on thresholds derived from older adults or occupationally active men.

Pregnancy-focused adaptation can be integrated into antenatal care. Clinicians and community health workers can counsel women about hydration, shaded rest, scheduling strenuous activity outside peak heat, recognizing heat illness, and seeking care for reduced fetal movement or concerning symptoms. However, individual behavior recommendations cannot substitute for structural adaptation when women lack reliable water, cooling, adequate housing, paid rest, or accessible maternity services.

Factors likely to modify heat-related pregnancy risk in LMICs are summarised in Table 4.

4. Discussion

4.1 Principal findings

The evidence available through 2023 supports a consistent association between environmental heat and adverse pregnancy outcomes, with particularly compelling findings for preterm birth and increasingly strong evidence for stillbirth. The LMIC literature is no longer limited to extrapolation from high-income countries. Multi-country DHS analyses, large South Asian and Chinese surveillance cohorts, national Ghanaian stillbirth data, and direct physiological work in The Gambia together demonstrate that heat risk is observable across multiple study designs and exposure metrics.

The magnitude of individual estimates is often modest, but this should not be interpreted as trivial. Heat exposure is population-wide, recurrent, and increasing. A small relative increase in preterm birth or stillbirth applied to millions of pregnancies can generate substantial public-health burden. Moreover, the highest risks may occur in women already facing limited healthcare access, adverse housing, outdoor work, and socioeconomic disadvantage.

4.2 Urban heat is important but not the whole problem

The planned urban focus requires nuance. Urban heat islands can amplify thermal exposure, particularly at night, and informal settlements may combine dense construction with inadequate ventilation and unreliable electricity. Nevertheless, the Ghanaian and Chinese data demonstrate that rural women can experience equal or greater heat-related risk [6,7]. This may reflect outdoor labor, lower access to cooling, travel burden, poverty, and local housing characteristics.

A useful framework is therefore not urban versus rural as a binary category, but total thermal exposure plus adaptive capacity. Urban women may face persistent nocturnal heat and high indoor exposure, while rural women may experience intense solar and occupational heat. Peri-urban settlements can combine both patterns.

4.3 Timing of exposure matters

Different outcomes appear to have different susceptibility windows. Acute exposure in the final week can precipitate preterm delivery, while the Ghanaian findings suggest that stillbirth risk may also accumulate across months of elevated thermal stress. The South Asian cohort identified second-trimester associations with preterm birth and low birth weight and third-trimester associations with gestational hypertensive disease [5]. This heterogeneity argues against treating pregnancy as a single uniform exposure period.

Future studies should therefore report trimester-specific and distributed-lag analyses rather than only pregnancy-average temperature. Short-term and long-term pathways should be analyzed separately because the biological mechanisms may differ.

4.4 Exposure measurement remains a major challenge

LMIC research is constrained by sparse meteorological monitoring and by the mismatch between outdoor station temperatures and personal heat exposure. Gridded remote-sensing products improve geographic coverage, but they cannot fully capture indoor heat, workplace solar radiation, clothing, workload, ventilation, or hydration. WBGT and UTCI incorporate additional thermal dimensions, while wearable sensors can directly quantify personal exposure and maternal physiological strain.

The optimal future design will combine satellite or reanalysis data with neighborhood sensors, indoor monitors, wearable temperature or physiological measurements, and time-activity information. This is especially important in cities where heat exposure can vary dramatically between neighborhoods and building types.

4.5 Clinical and policy implications

Pregnancy should be explicitly incorporated into heat-health action plans. Antenatal services can identify high-risk women and communicate heat precautions, but effective adaptation must also address work, housing, water, transportation, and energy. Heat alerts that simply advise people to remain indoors may be ineffective when indoor temperatures are higher than outdoors or when women cannot stop paid or subsistence work.

Locally validated thresholds are essential. A temperature considered moderate in one climate may produce substantial physiological strain when humidity is high, ventilation is poor, or physical work is required. Likewise, prolonged hot nights may create cumulative load even when daytime maximum temperature does not cross an emergency threshold.

The evidence-informed maternal heat-adaptation framework for LMIC settings is presented in Table 5.

4.6 Strengths and limitations

This synthesis applies a strict evidence cutoff and emphasizes high-quality Q1 literature while prioritizing direct LMIC studies. It integrates epidemiological, physiological, and health-system perspectives and avoids presenting non-comparable effect estimates as a single pooled value.

Several limitations remain. The definition of extreme heat varied widely, and temperature exposure was often assigned from area-level data rather than personal monitoring. Preterm birth and stillbirth definitions can differ across surveillance systems. Residual confounding by air pollution, season, socioeconomic position, infection, nutrition, and healthcare access is possible. Some large datasets rely on reported gestational age or retrospective survey information. The evidence base also remains geographically uneven, with relatively few high-quality studies from many African, South Asian, and rapidly urbanizing settings.

4.7 Conclusion

High ambient temperature and heat waves are associated with adverse pregnancy outcomes, and evidence available by the end of 2023 demonstrates that this risk extends directly to low- and middle-income countries. Preterm birth has the most consistent evidence, while stillbirth, low birth weight, gestational hypertensive disease, and acute fetal strain are also supported by increasingly strong data.

The results do not support a narrow interpretation in which urban residence alone defines vulnerability. Urban heat islands, poor housing and hot nights are important, but rural occupational exposure, limited cooling, poverty, nutrition, water insecurity and healthcare access can produce equal or greater risk. The most useful policy framework therefore combines environmental heat measurement with social and clinical vulnerability.

Maternal heat protection should become a routine component of climate adaptation and antenatal health planning. Locally validated heat-warning thresholds, occupational safeguards, hydration and cooling access, heat-resilient housing, continuity of maternity services and better pregnancy-specific exposure data are practical priorities. As global temperatures rise, protecting pregnancy from heat should be treated as both a maternal-health and climate-resilience objective.

Declarations

Funding

No external funding was received.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

Not applicable. This manuscript synthesized previously published evidence and did not involve direct participant recruitment.

Consent to Participate

Not applicable.

Data Availability

No novel participant-level dataset was generated.

Author Contributions

The authors contributed to conceptualization, evidence synthesis, interpretation, manuscript preparation, and critical revision.

References

1. Ebi KL, Capon A, Berry P, Broderick C, de Dear R, Havenith G, et al. Hot weather and heat extremes: health risks. Lancet. 2021;398(10301):698-708. doi:10.1016/S0140-6736(21)01208-3.

2. Chersich MF, Pham MD, Areal A, Haghighi MM, Manyuchi A, Swift CP, et al. Associations between high temperatures in pregnancy and risk of preterm birth, low birth weight, and stillbirths: systematic review and meta-analysis. BMJ. 2020;371:m3811. doi:10.1136/bmj.m3811.

3. McElroy S, Ilango S, Dimitrova A, Gershunov A, Benmarhnia T. Extreme heat, preterm birth, and stillbirth: a global analysis across 14 lower-middle income countries. Environ Int. 2022;158:106902. doi:10.1016/j.envint.2021.106902.

4. Bonell A, Sonko B, Badjie J, Samateh T, Saidy T, Sosseh F, et al. Environmental heat stress on maternal physiology and fetal blood flow in pregnant subsistence farmers in The Gambia, west Africa: an observational cohort study. Lancet Planet Health. 2022;6(12):e968-e976. doi:10.1016/S2542-5196(22)00242-X.

5. Shankar K, Hwang K, Westcott JL, Saleem S, Ali SA, Jessani S, et al. Associations between ambient temperature and pregnancy outcomes from three south Asian sites of the Global Network Maternal Newborn Health Registry: a retrospective cohort study. BJOG. 2023;130(Suppl 3):124-133. doi:10.1111/1471-0528.17616.

6. Nyadanu SD, Tessema GA, Mullins B, Kumi-Boateng B, Ofosu AA, Pereira G. Prenatal exposure to long-term heat stress and stillbirth in Ghana: a within-space time-series analysis. Environ Res. 2023;222:115385. doi:10.1016/j.envres.2023.115385.

7. Guo Y, Chen P, Xie Y, Wang Y, Mu Y, Zhou R, et al. Association of daytime-only, nighttime-only, and compound heat waves with preterm birth by urban-rural area and regional socioeconomic status in China. JAMA Netw Open. 2023;6(8):e2326987. doi:10.1001/jamanetworkopen.2023.26987.

8. Yüzen D, Graf I, Tallarek AC, et al. Increased late preterm birth risk and altered uterine blood flow upon exposure to heat stress. EBioMedicine. 2023;93:104651. doi:10.1016/j.ebiom.2023.104651.

9. Bekkar B, Pacheco S, Basu R, DeNicola N. Association of air pollution and heat exposure with preterm birth, low birth weight, and stillbirth in the US: a systematic review. JAMA Netw Open. 2020;3(6):e208243. doi:10.1001/jamanetworkopen.2020.8243.

10. Sexton J, Andrews C, Carruthers S, Kumar S, Flenady V, Lieske S. Systematic review of ambient temperature exposure during pregnancy and stillbirth: methods and evidence. Environ Res. 2021;197:111037.

11. Sun S, Weinberger KR, Spangler KR, Eliot MN, Braun JM, Wellenius GA. Ambient temperature and preterm birth: a retrospective study of 32 million US singleton births. Environ Int. 2019;126:7-13. doi:10.1016/j.envint.2019.02.023.

12. Chawanpaiboon S, Vogel JP, Moller AB, Lumbiganon P, Petzold M, Hogan D, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. Lancet Glob Health. 2019;7(1):e37-e46. doi:10.1016/S2214-109X(18)30451-0.

Table 1. Eligibility framework

Domain	Inclusion criteria	Exclusion criteria
Publication period	Published on or before 31 December 2023	2024 onward
Journal quality	Q1 journal in obstetrics, environmental health, planetary health, medicine, or related field	Lower-quartile or unranked sources
Population	Pregnant populations in LMICs; global reviews with directly relevant pregnancy evidence	Non-pregnant populations without mechanistic relevance
Exposure	Ambient heat, heat waves, Tmax, WBGT, UTCI, or equivalent thermal exposure	Temperature unrelated to environmental heat
Outcomes	Preterm birth, stillbirth, low birth weight, hypertensive disease, fetal strain, fetal growth	Outcomes without pregnancy relevance
Design	Systematic review/meta-analysis, cohort, case-crossover, time-series, physiological field study	Unsupported commentary
Synthesis	Published estimates retained on their original scale	Artificial pooling of non-comparable effect measures

Table 2. Major pre-2024 Q1 studies directly relevant to LMIC heat and pregnancy outcomes

Study	Setting and sample	Exposure	Principal finding
McElroy et al. 2022 [3]	14 lower-middle-income countries; >103,000 births from DHS data	Gridded maximum temperature and diurnal temperature range; acute late-pregnancy exposure	Higher maximum temperature and smaller diurnal temperature range in the final week were associated with greater preterm-birth and stillbirth risk
Bonell et al. 2022 [4]	Pregnant subsistence farmers, The Gambia	WBGT, UTCI and directly measured maternal heat strain during field work	Heat exposure and maternal heat strain were associated with acute fetal strain
Shankar et al. 2023 [5]	126,273 pregnancies in Belagavi, Nagpur and Thatta, India/Pakistan	Trimester-average daily maximum temperature	Second-trimester heat associated with PTB and LBW; third-trimester heat associated with gestational hypertensive disease
Nyadanu et al. 2023 [6]	5,961,328 births and 90,532 stillbirths across Ghana	District-level UTCI; long-term thermal stress	Higher-moderate heat stress associated with greater stillbirth risk, with stronger vulnerability in rural/low-density districts
Guo et al. 2023 [7]	5,446,088 singleton births in China	Daytime-only, nighttime-only and compound heat waves in final week	Compound and daytime-only heat waves associated with PTB; daytime effects stronger in rural women
Chersich et al. 2020 [2]	70 studies across 27 countries	Multiple ambient-temperature and heat-wave measures	PTB odds +5% per 1°C and +16% during heat waves; harmful stillbirth pattern across all 8 studies

Table 3. Outcome-specific interpretation of the pre-2024 evidence

Outcome	Evidence pattern	Likely susceptible window	Interpretation
Preterm birth	Most consistently studied; positive associations across meta-analysis, 14-LMIC study, South Asia and China	Often final days/weeks; some trimester-specific effects	Heat may trigger labor acutely and may also influence gestational pathways over longer exposure
Stillbirth	All eight studies in 2020 review harmful; acute LMIC evidence and long-term Ghana association	Late pregnancy prominent, but long-term cumulative exposure may also matter	Evidence increasingly supports both acute and cumulative thermal stress
Low birth weight	Mixed but predominantly harmful evidence; South Asian trimester-specific association	Early or mid-pregnancy depending on site	Growth effects may involve placental function, maternal nutrition and prolonged thermal stress
Gestational hypertensive disease	South Asian cohort found higher risk with third-trimester temperature	Late pregnancy in direct LMIC evidence	Heat-related cardiovascular and fluid-balance stress may contribute
Fetal strain	Directly observed during real-world heat exposure in The Gambia	Immediate exposure during work	Supports biological plausibility for epidemiological associations
Stillbirth burden modification	Greater risk in rural/lower-resource Ghanaian districts	Cumulative pregnancy exposure	Adaptive capacity and socioeconomic context modify thermal risk

Table 4. Factors likely to modify heat-related pregnancy risk in LMICs

Modifier	Potential mechanism	Implication
Urban heat island and hot nights	Reduced nocturnal heat dissipation and higher indoor temperatures	Warnings should incorporate minimum/nighttime temperature and neighborhood heat
Outdoor or manual work	Adds metabolic heat and solar exposure to ambient load	Occupational protections and rest schedules are required
Housing quality	Metal roofing, crowding and poor ventilation can intensify indoor heat	Housing and passive-cooling interventions may be maternal-health interventions
Water access	Dehydration can worsen cardiovascular strain	Heat plans require reliable safe drinking water
Electricity and cooling access	Limits fans, refrigeration and air conditioning	Behavioral advice may be ineffective without infrastructure
Nutrition and anemia	May reduce physiological resilience and fetal growth reserve	Heat adaptation should integrate maternal nutrition programs
Rurality and travel distance	Long journeys and delayed care during heat can increase risk	Community-level services and transport planning are important
Comorbidity and gestational stage	Hypertension and late pregnancy can increase vulnerability	Clinical risk stratification may improve targeting
Air pollution	Heat can co-occur with ozone and particulate pollution	Multi-exposure models are preferable to temperature-only models

Table 5. Evidence-informed maternal heat-adaptation framework for LMIC settings

Level	Recommended action	Purpose
Antenatal care	Identify pregnancy as a heat-vulnerability state; provide hydration, rest and warning education	Improve recognition and self-protection
Clinical triage	Include recent heat exposure when assessing contractions, dehydration, reduced fetal movement or hypertensive symptoms	Improve contextual risk assessment
Occupational policy	Provide shade, water, paid rest and rescheduling of strenuous work	Reduce combined metabolic and environmental heat load
Community heat warnings	Use locally calibrated thresholds and pregnancy-specific messaging	Target alerts to clinically vulnerable groups
Housing	Promote passive cooling, ventilation, reflective roofing and heat-resilient settlement design	Reduce indoor and nighttime heat exposure
Health services	Maintain transport, electricity, water and maternity access during extreme heat events	Protect continuity of care
Data systems	Link birth registries with meteorological and neighborhood heat data	Enable local risk estimation
Research	Measure personal exposure, indoor temperature, occupation and repeated gestational windows	Improve causal inference and intervention design

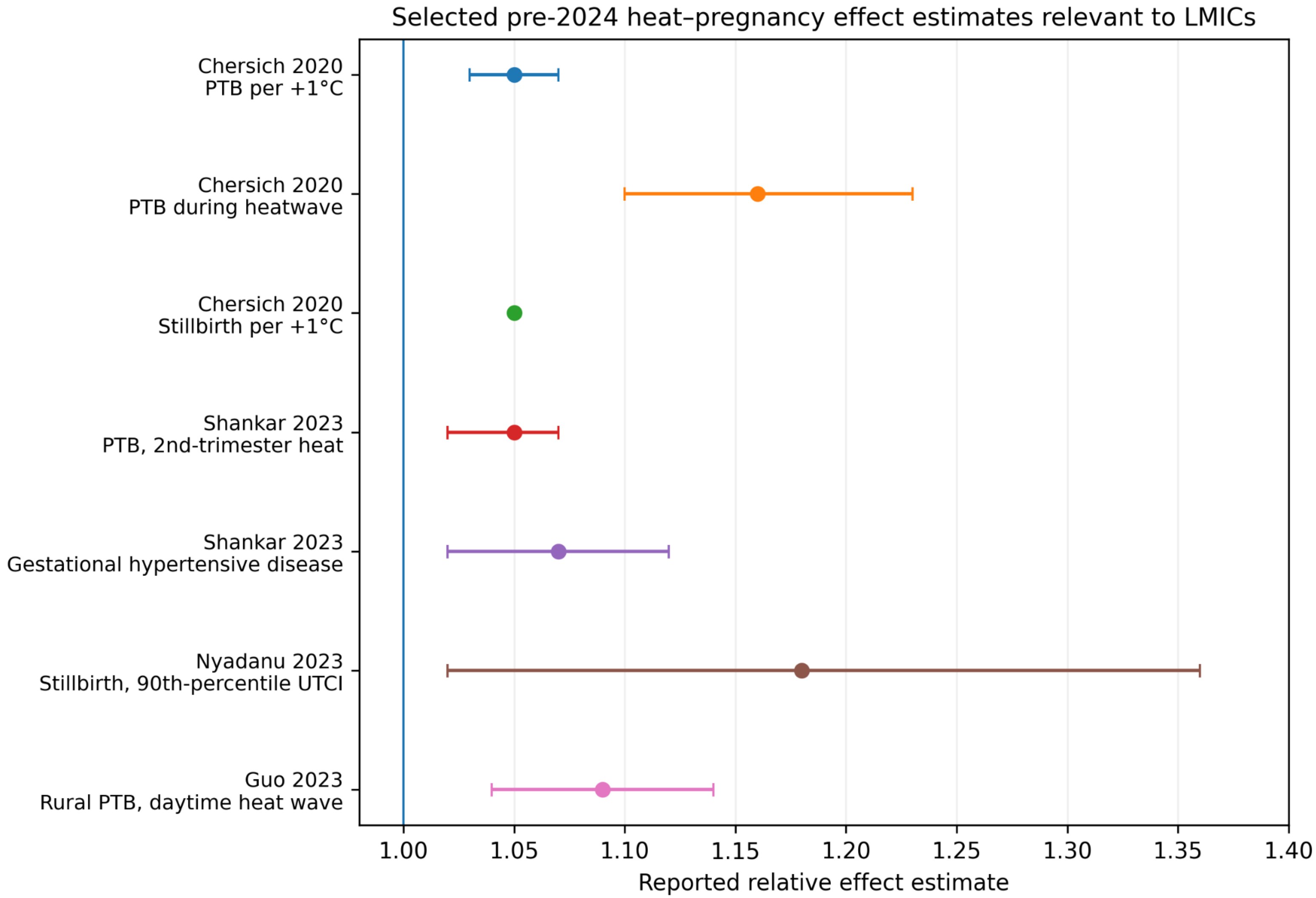

Figure 1. Selected pre-2024 heat–pregnancy effect estimates relevant to LMICs.

Published estimates are shown on their original scales and are not statistically pooled.

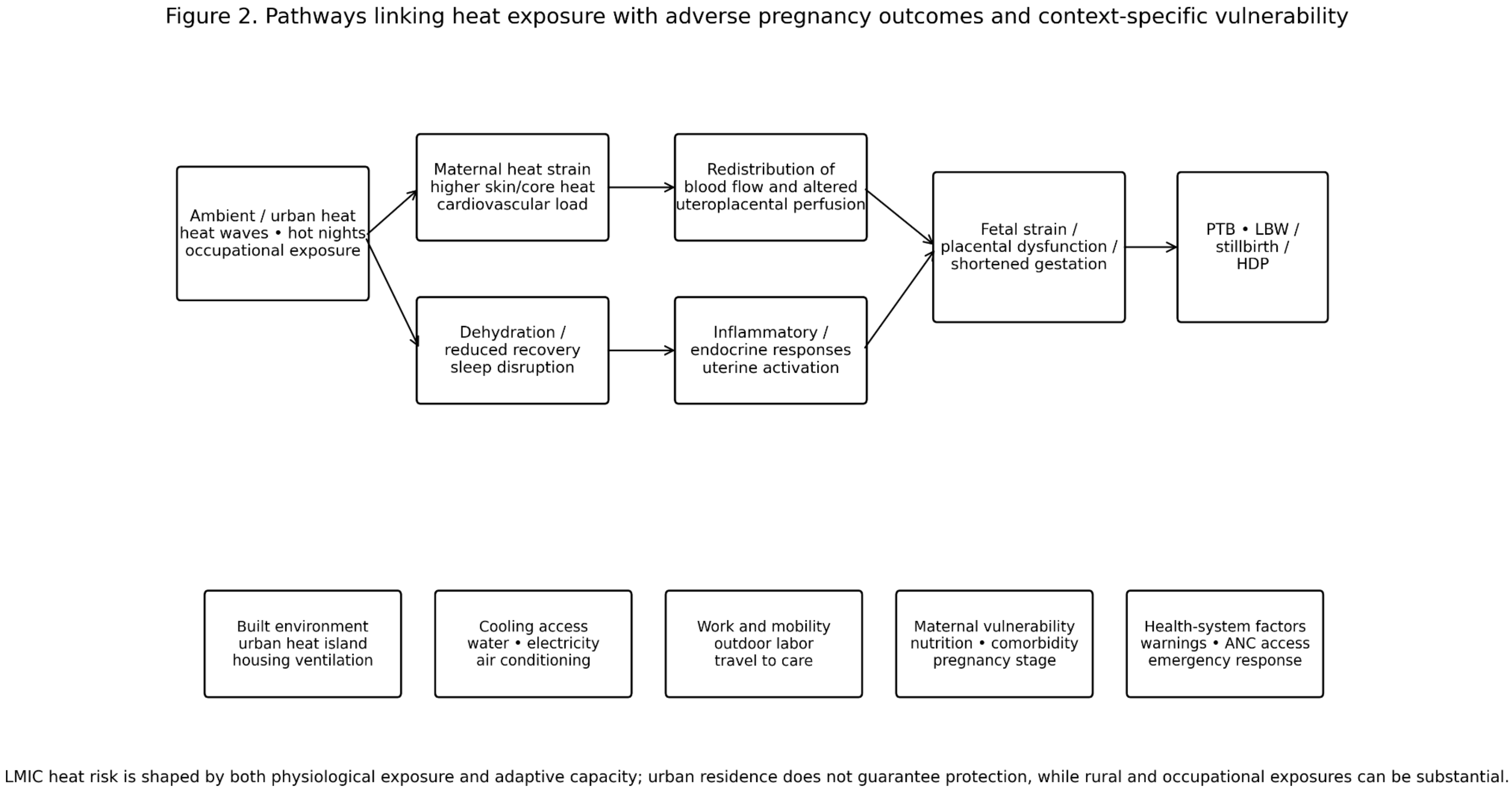

Figure 2. Pathways linking heat exposure with adverse pregnancy outcomes and context-specific vulnerability.

The framework links ambient, urban and occupational heat with maternal heat strain, dehydration, altered uteroplacental perfusion, inflammatory or endocrine responses and fetal strain. Built environment, cooling access, work, maternal vulnerability and health-system capacity modify exposure and adaptive capacity.

How to cite: **Mensah S. (2024). Urban Heat Exposure and Adverse Pregnancy Outcomes in Low- and Middle-Income Countries: A Systematic Evidence Synthesis. Journal of Multidisciplinary Research and Integrated Sciences, 4(1).**