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By Theodore James Davies and John Rand

Introduction

Child health and education outcomes are critical priorities in global development policy, forming core elements of the United Nations' Sustainable Development Agenda (UN, 2015). However, it is increasingly evident that the climate crisis poses significant threats to further progress in these areas (IPCC, 2023). These threats are particularly severe in high-temperature, low-income regions, where both individuals and governments face limited capacity to adapt to extreme heat and weather events. Despite a growing body of evidence on the economic and health impacts of climate change, many of these impacts and their underlying mechanisms remain poorly understood (WHO, 2023). This article aims to deepen our understanding of one such impact — the effect of heat exposure during pregnancy on childhood outcomes. In so doing, it contributes to the broader discussion on the relationship between heat exposure and outcomes in health and development.

The latest report from the Intergovernmental Panel on Climate Change (IPCC) concludes that human activities have led to an increase in the average global surface temperature of approximately 1.1°C, compared to the period between 1850 and 1900 (IPCC, 2023). In addition to this overall rise in ambient temperatures, the report concludes that it is "virtually certain" that extreme heat events (heatwaves) are becoming more frequent and intense. Furthermore, the report finds that global warming is having significant impacts on humans and their activities. For instance, the IPCC concludes that climate change has very likely reduced agricultural productivity, exacerbated food scarcity, increased the spread of infectious diseases, and diminished livelihood opportunities. These effects are most pronounced in highly vulnerable regions, which are characterized by factors such as poverty, limited government capacity, and dependence on small-scale agriculture (*ibid*.).

These trends are expected to persist over time and may even accelerate. According to IPCC SSP emission scenarios and extensive experimental data (see Eyring et al., 2016), projections for the increase in global average temperature by 2100 range from 1.4°C (SSP1) to 4.4°C (SSP5) (IPCC, 2023).

An understanding of these patterns of heat exposure, as well as their impacts, thus seems set to become even more integral to global development and health policy. One category of heat exposure on which there has been growing academic attention is that occurring before birth. This article draws together relevant evidence in this area, to explain why this may be of particular concern, and to evaluate whether this concern has empirical support.

Before the more detailed review of the prenatal heat exposure literature, we briefly set out prevailing approaches to the scientific definition and measurement of heat exposure. Following this, we divide the evidence surrounding prenatal heat exposure into two broad categories of impacts: direct impacts on fetal physiology and fetal survival; and impacts produced through changes in the postnatal inputs children receive.

While we find that there is some compelling evidence for specific pathways of impact in both categories, we conclude that our overall understanding of these issues is significantly constrained by the persistence of wide research gaps and methodological inconsistencies. This is striking, given that the extant body of literature gives reason to believe that these impacts may be highly consequential for the health and wellbeing of children, especially those in parts of the Global South.

In particular, we find five key limitations in research published to date: (1) A lack of studies that investigate long-term developmental outcomes beyond the prenatal and neonatal stages; (2) An absence of studies on long-term outcomes using heat indices, rather than metrics based on temperature alone; (3) Inconclusive evidence regarding critical exposure windows and thresholds for heat-related impacts; (4) Limited research in high-vulnerability settings, particularly in regions with high heat exposure, low income, and limited capacity to mitigate the effects of heat; and (5) Insufficient evidence on which pathways contribute most significantly to long-term developmental outcomes. Addressing these gaps would advance our understanding of how prenatal heat exposure influences child outcomes over time.

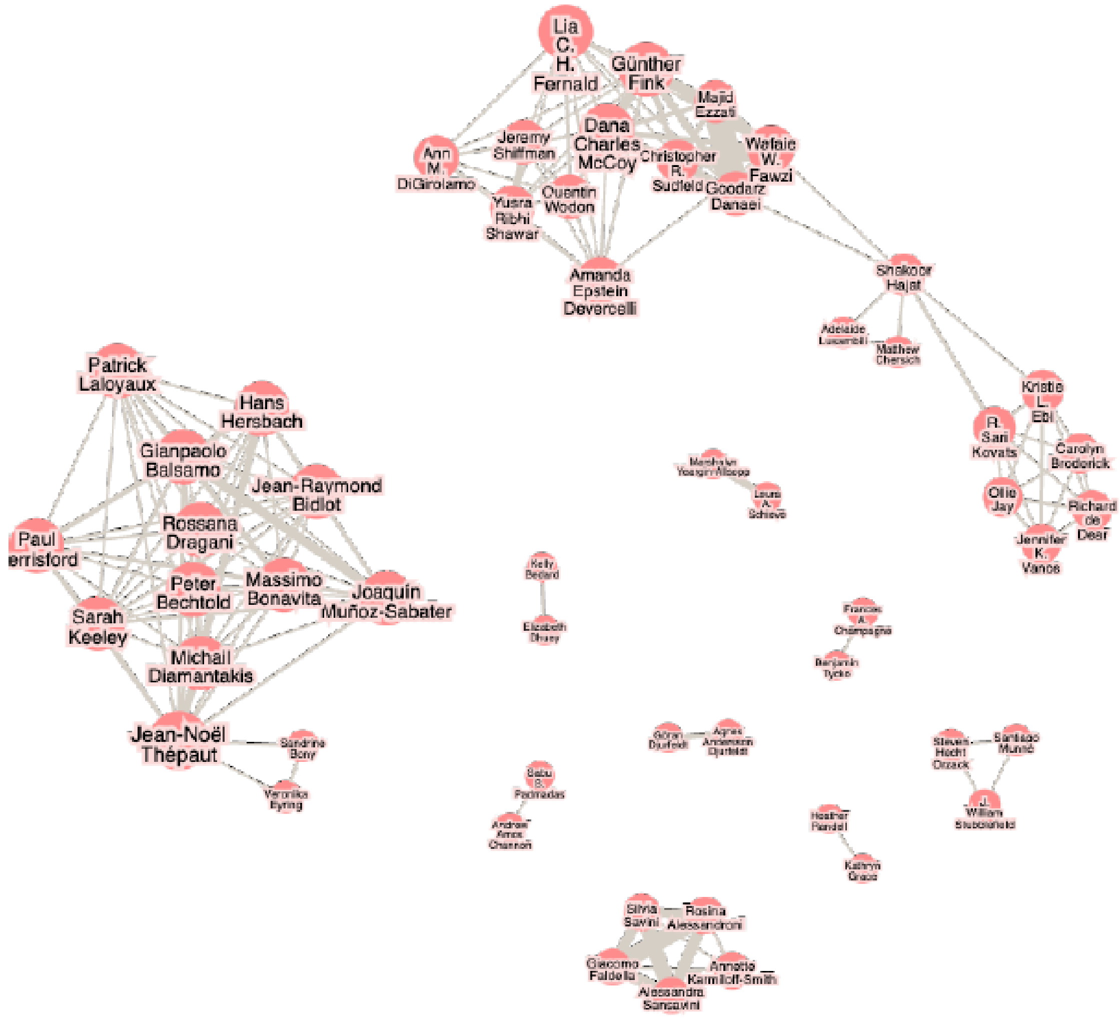
Review methodology

To identify relevant research a comprehensive search was carried out across multiple databases, including Web of Science, Scopus, PubMed, and the Royal Danish Library. Articles were identified using the keywords: “definition and measurement of heat exposure,” “physiological consequences of heat exposure,” “heat exposure and fetal survival,” “heat exposure and child development,” “prenatal heat exposure and child development,” and “childcare and heat exposure”. Studies were included if they met the following criteria: (1) It reported or referenced quantitative data on the effects of prenatal heat exposure and (2) The article was published in a journal with a Scopus based impact factor, using SJR, CiteScore, or SNIP as metrics. Studies were excluded if they: (1) Focused solely on qualitative analysis without referencing quantitative outcomes or (2) Focused exclusively on the COVID 19 period. Articles written in languages other than English and those without accessible full texts were also excluded.

After removing duplicates and applying the inclusion/exclusion criteria described we narrowed our focus to articles with the highest Source Normalized Impact per Paper (SNIP). Titles and abstracts were screened for relevance to the research question, targeting 50 articles. Full-text assessments followed, with data extraction focusing on study characteristics (author, year, design); (2) population characteristics (sample size, target population); and (3) main outcomes (fetal related impacts of heat exposure).

The final set of 50 articles selected for the systematic review provides a comprehensive evidence base for assessing prenatal heat exposure to development and health outcomes. To further explore the relationships between included studies and subsequent research, Figure 1 shows a citation mapping graph generated by the AI tool Research Rabbit. This graph visually represents the interconnectivity of the most connected papers, selected by Research Rabbit based on our selection of articles. The graph highlights the relative influence of specific papers, with central nodes indicating foundational studies that later works rely on. The cluster divisions do to a large extent represent different topics and science fields.

Figure 1: Author networks

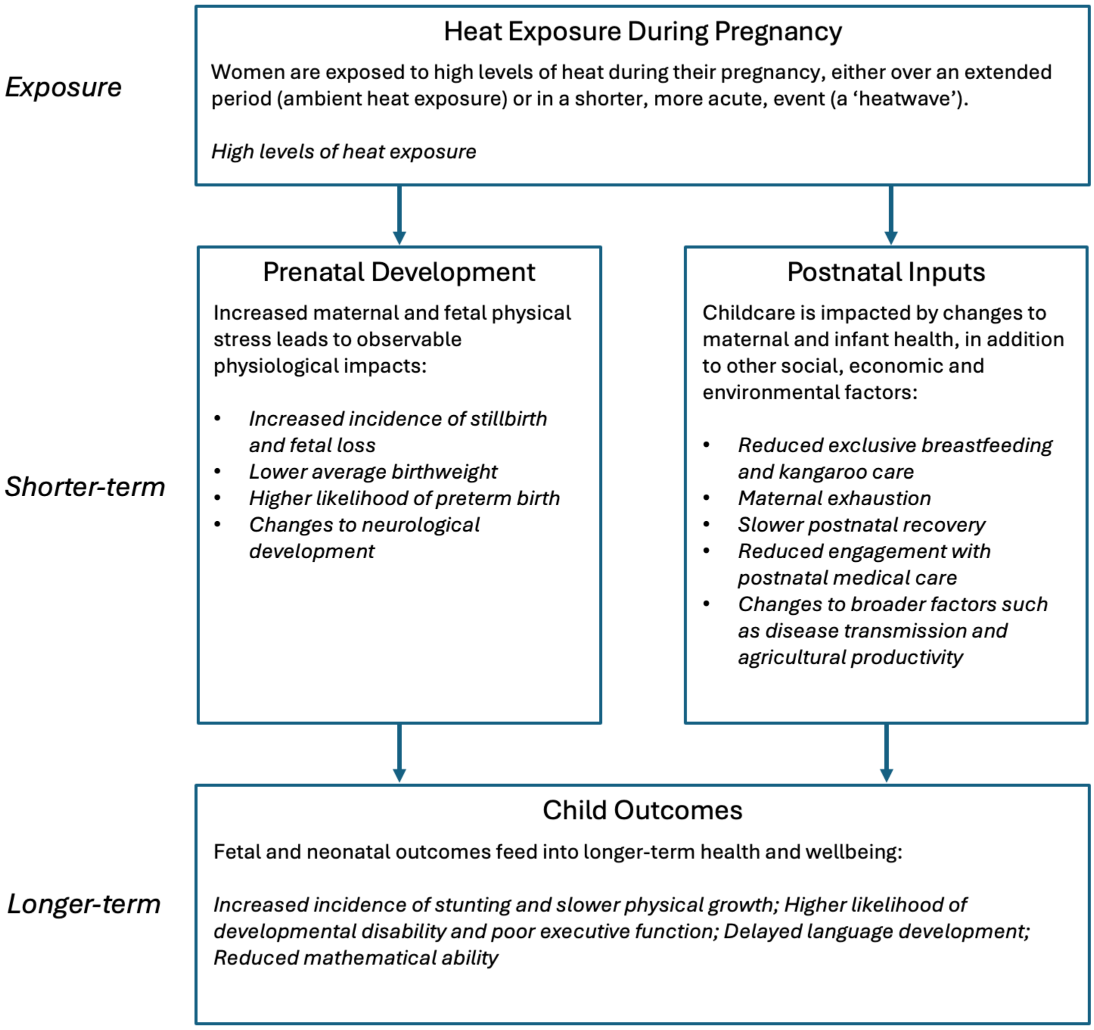


Framework

The existing literature on this topic is diffuse, both in terms of discipline and methodology. To bring together these disparate strands, we will use the general conceptual framework set out in Figure 2. As well as providing a headline theoretical grasp of why we may expect heat exposure to impact longer-term child outcomes, this framework also enables us to draw upon and locate empirical studies that address only one stage of these channels of impact. This is particularly valuable because—as will become apparent—there is very little evidence directly assessing the longer-term impacts of prenatal heat exposure. For this reason, the preponderance of the literature reviewed here focuses either on how prenatal heat exposure relates to fetal and neonatal outcomes, or on how these fetal and neonatal outcomes relate to child outcomes.

In Figure 2, the italicised text describes the specific factors and outcomes for which there is at least some empirical evidence that supports their relevance. This is not only to link individual studies back to the framework, but also to reiterate the substantial scope, complexity and importance of these channels of impact: a single family of exposures is linked to varied shorter-term health, social and developmental impacts, which are themselves then related to numerous basic components of child health, wellbeing and education.

Figure 2: Conceptual Framework



Defining and measuring heat exposure

A recent article by Brimicombe et al. (2024) concludes that the existing literature on the relationship between heat exposure and maternal and infant health has not yet fully captured the complexity of heat exposure. We will therefore start by setting out some basic points concerning the nature and definition of heat exposure, so that we are better placed to evaluate the literature, and the conclusions that it is, or is not, able to support.

Heat exposure is often equated with high temperature alone. However, this view understates the complexity of heat and its relationship to people and their environments. As McGregor and Vanos (2018) emphasise, "heat as a physical term is a complex phenomenon resulting from the interactions of a range of environmental variables". Based on a review of the literature, they identify four key factors that together determine the level of heat exposure: (i) temperature, (ii) humidity, (iii) ventilation, and (iv) radiation. Humidity plays a critical role because it is inversely related to the air's capacity to absorb additional moisture. When humidity is high, sweat evaporates less effectively, making it harder for the body to regulate its temperature. Ventilation, primarily wind speed, is also important, since stronger winds enhance turbulent cooling, thereby reducing individual heat exposure. Radiation refers to the direct heating from the Sun's electromagnetic radiation (and other radiation sources), as opposed to heat transferred from air temperature. In areas with clear skies and minimal atmospheric protection, such as near the Equator, radiation exposure is particularly high.

To address the complexity of heat exposure, which is not reducible to air temperature alone, several compound measures have been developed (McGregor, 2024). Heat Index has become the standard measure of high heat exposure for various U.S. government agencies and has been widely adopted in the scientific community, although approximating algorithms are necessary due to the complexity of the original calculation method developed by Steadman (Brooke Anderson et al., 2013). The main advantage of Heat Index is that it can be calculated using widely available input data with extensive historical records (air temperature and relative humidity), and produces a metric on a Celsius or Fahrenheit scale. However, the most common forms do not consider either ventilation or radiation, which limits its ability to accurately track exposure (McGregor and Vanos, 2018).

Other measures, such as the Wet-Bulb Globe Temperature (WBGT) and the Universal Thermal Comfort Index (UTCI), have also been developed. Like Heat Index, these scales convert various inputs into Fahrenheit or Celsius scales. WBGT is sometimes preferred to Heat Index due to concerns about the latter's computational complexity (McGregor, 2024). However, WBGT and UTCI require less commonly available input data than the Heat Index (or a similar measure, Humidex) (*ibid*.). For instance, WBGT needs data from three different types of thermometers for each observation, and UTCI requires information on clothing, wind speed, and activity level. This makes them less practical in empirical settings where such data is either unavailable or inconsistent.

As McGregor and Vanos (2018, p. 144) suggest, each measure of heat exposure has its appropriate "time and place". While the more complex measures incorporate more of the four exposure factors, and thus offer deeper insights into the heat exposure individuals may experience in specific situations, they are often challenging to measure, calculate, and interpret. Use of air temperature alone can be understood as the other extreme of this trade-off: it maximises measurability and interpretability, but also reduces heat exposure to one of its four dimensions. Thus, while it is undoubtedly a suitable metric in some contexts, basing our understanding of heat exposure on research using only temperature is by definition a limited approach.

Even once an underlying heat exposure metric has been selected, there remains the choice of how to use this metric to decide if someone has been exposed to a high level of heat. There are two main methods of doing this: to measure exposure continuously using the raw metric (e.g. heat exposure equals heat index in degrees Celsius); or to define high heat exposure as anything exceeding a particular threshold (e.g. high heat exposure is air temperature above 25 degrees Celsius). Moreover, there is also the choice of relevant exposure window – how long does heat exposure have to be elevated above the relevant threshold, and how long a period should exposure be averaged over? In the following sections, we will see that there is little cross-study agreement on either the use of binary or continuous exposure measures, or on the choice of exposure window length.

Physiological consequences of heat exposure

One way in which we may expect prenatal heat exposure to impact outcomes is via its impact on the body – its physiological consequences. In general, the body responds to heat exposure through two main mechanisms: vasodilation, the redirection of blood flow to the skin and away from the core; and perspiration, or sweating (Ebi et al., 2021). The former process helps cool the body by bringing the warm blood closer to the air into which it can radiate heat, and the latter does so by using heat to evaporate the excess sweat. However, the body's thermoregulatory capacity is limited and can lead to negative physiological effects, as vasodilation increases cardiac load, and sweating can cause dehydration (ibid.). When internal body temperatures reach 39-40°C, serious organ damage and even death can occur (ibid.). Pregnant women are particularly vulnerable to heat exposure due to the changes pregnancy brings to their thermoregulatory capacity. For instance, pregnancy results in fat and weight gain and increased cardiac load, and, in addition, both the metabolic demands of the fetus and the exertion of childbirth itself generate significant quantities of heat (Chersich et al., 2023).

Chersich et al. (2023) outline four pathophysiological "pathways" through which heat exposure may impact maternal and neonatal health. (i) Elevated body temperatures: There is evidence linking even slightly elevated maternal body temperatures with adverse neonatal outcomes. Maternal temperatures above 39°C can have "severe" consequences for fetal health. (ii) Dehydration: Maternal dehydration can cause renal and cardiovascular dysfunction, negatively affecting fetal development. (iii) Endocrine dysfunction: High temperatures can trigger the production of heat shock proteins and stress hormones, which are connected to placental development. (iv) Placental growth: Heat exposure can reduce placental size, possibly due to blood being redirected to the skin, which impairs fetal nutrition and growth.

Most evidence for these pathways comes from experimental studies, predominantly relying on animal subjects due to ethical concerns about human participation. In fact, Bonell et al. (2022) describe their research as the first real-world examination of these pathophysiological pathways in humans. In a small-scale study (n=92) conducted with mothers in The Gambia, they investigate the relationship between heat stress (measured by WBGT and UTCI), maternal heat strain (assessed through heart rate and skin temperature), and fetal strain (determined by fetal heart rate). They find a significant link between heat stress and fetal strain, even after controlling for maternal heat strain. However, they note that evidence linking heat to pregnancy outcomes in Africa remains "sparse".

A recent qualitative study in rural Kenya also supports the association between heat stress and increased maternal strain (Scorgie et al., 2023). Expectant mothers reported feeling hot, dehydrated, and dizzy in high-heat conditions, along with experiencing disrupted sleep (ibid., p. 4). Importantly, this heat stress was worsened by social factors—pregnant women in this community are expected to perform strenuous outdoor labour, even late in pregnancy, with little to no mitigation (ibid., p. 5). These findings are consistent with another small-scale qualitative study in The Gambia (Spencer et al., 2022), suggesting that these issues may be common across Sub-Saharan Africa. While the pathophysiological mechanisms linking heat and maternal and child health are not yet fully understood, there is growing evidence connecting heat exposure to specific adverse birth outcomes, to which we turn next.

Heat and fetal survival

A recent review by Bonell et al. (2023) concludes that there is a clear positive association between high heat exposure during pregnancy and an increased risk of stillbirth. This finding is further supported by a meta-analysis from Chersich et al. (2020), which concludes that this risk is elevated both for exposure to high temperatures in the week leading up to childbirth and for exposure throughout the entire pregnancy. The odds ratio for stillbirth incidence following short-term heat exposure was estimated at 1.24 (1.12-1.36, 95% CI), while for prolonged exposure across pregnancy, it was estimated at 3.39 (2.33-4.96, 95% CI). This is indicative of a highly significant impact of heat exposure. A preprint study by Hanson et al. (2024) expands this evidence base to four Sub-Saharan African countries, providing further empirical support for a relationship between short-term heat exposure and stillbirth risk.

These studies use different metrics and definitions for high heat, leading Bonell et al. (2023, p. 3) to refrain from identifying a universal heat threshold beyond which stillbirth risk increases. They note, however, that the link is evident for temperatures above the 90th percentile experienced by the population in question. Similarly, Baharav et al. (2023, p. 330) write that "A lack of globally consistent definitions and criteria for heat exposure limits researcher and practitioner ability to provide guidance on which heat conditions are dangerous for pregnant individuals and neonates". Syed et al. (2022) concur, concluding that: "Use of precise temperature data by most studies avoided pitfalls of imprecise, regional definitions of heat waves, however inconsistent study design and exposure windows are a significant challenge to systematic evaluation of this literature". Moreover, they further extend this critique, arguing that there is a "systematic gap in the epidemiological literature" when it comes to heat exposure and the global south, even though these areas are characterised by a "high risk of extreme heat events and limited mitigation strategies".

One potential corollary to this link between heat exposure and stillbirth is proposed by Wilde et al. (2017, p. 89). These authors suggest that stillbirths arising because of heat exposure may be more likely to affect the weakest and most vulnerable fetuses. Perhaps counterintuitively, this selection effect could result in improved average child development outcomes, as only 'stronger' fetuses survive into childhood. While they find some tentative support for this mechanism, it currently lacks a definitive empirical basis.

Heat exposure impacts fetal development

Heat exposure has been shown to affect fetal development beyond stillbirth and any selection effect, particularly by its relation to the incidence of preterm birth and low birthweight. Research indicates that the incidence of both increases significantly with higher temperatures during pregnancy (Chersich et al., 2023). Specifically, a meta-analysis by Chersich et al. (2020) found that the odds of preterm birth rise by 5% (3-7%, 95% CI) for every 1°C increase in temperature across pregnancy. The odds of preterm birth were estimated to increase by 16% (10-23%, 95% CI) during heatwaves, where these are defined as periods of at least 2 days above the 90th percentile for temperature. Additionally, these authors find that babies exposed to high temperatures in utero weigh, on average, 25.5g (15.0-39.4g, 95% CI) less than those born in cooler conditions. However, on this latter point they are unable to provide precise definition of 'high' and 'low' temperature, because of the inconsistency in the approaches taken by the individual studies they synthesise.

There is a small amount of evidence suggesting that these effects may be more pronounced for exposures early in pregnancy and for individuals from disadvantaged socioeconomic backgrounds (Keivabu Conte and Cozzani, 2022). However, as before, Syed et al. (2022) argue that there is a paucity of studies from the Global South regarding these birth outcomes. Some exceptions exist, such as Grace et al. (2015), who find a link between climate factors (temperature and precipitation) and birthweight across 19 African countries. Similarly, the ENBEL network of climate change and health research projects found that in South Africa, women living with HIV face a higher risk of heat-related preterm birth, while other individual factors, such as the mother's age, do not seem to influence this risk (ENBEL, 2023). In a large Chinese city, Zheng et al. (2018) identified that the critical exposure periods for preterm birth related to higher ambient temperatures appeared to be the month of conception and the third trimester, with a stronger correlation observed in female fetuses compared to males.

Other fetal development outcomes have also been associated with heat exposure. For instance, birth complications like fetal distress, ventilator use, and meconium aspiration syndrome are more likely if a heatwave occurred during pregnancy (Cil and Cameron, 2017). Using data from Massachusetts hospitals, Leung et al. (2023) find that higher weekly temperatures are linked to reductions in ultrasound measures of fetal growth, such as head circumference, femur length, and abdominal circumference. They also determine that the first 20 weeks of pregnancy are the critical exposure period for these measures, whereas birthweight appears to be influenced by heat exposure throughout the entire pregnancy.

While these studies agree that there are effects on fetal development related to heat exposure, especially lower birthweight and higher incidence of preterm birth, their findings are hard to integrate. There is little overlap in the definition of heat exposure, the thresholds and windows used, and the outcomes and interactions considered. Without a more standardised approach on these points, it will be challenging to create the detailed empirical basis that is required to develop specific policy interventions targeted at mitigating these impacts.

Fetal development impacts child development

Prenatal maternal stress has been associated with a variety of child development outcomes, including numerous emotional, behavioural, and cognitive issues (Lautarescu et al., 2020, p. 18). These authors highlight three key findings from neurological studies examining the link between maternal stress and child development: (i) Macrostructure: Elevated maternal stress during pregnancy is linked to significant structural changes in the child’s brain, particularly reductions in grey matter volume and alterations in the frontal and temporal lobes. (ii) Microstructure: Increased levels of maternal stress in utero are associated with significant molecular changes in the child’s brain tissue, especially in the white matter of the frontal and limbic regions. (iii) Activity: Higher maternal stress levels during pregnancy are linked to significant alterations in brain activity patterns in the child, particularly in how the amygdala interacts with other brain regions.

There is also an established connection between certain fetal development outcomes and child development. For instance, a review by Martínez-Nadal and Bosch (2021) finds that children born preterm often exhibit developmental deficits in critical areas such as cognitive function, executive function, and academic performance, although some evidence suggests a 'catch-up' effect that may mitigate these deficits later in childhood (Baumann et al., 2024). Additionally, preterm birth has been linked to mathematical difficulties (Taylor et al., 2009) and an atypical trajectory in language development, including delays in vocabulary, reading speed, and grammar (Guarini et al., 2010). Moreover, both preterm birth and low birthweight are associated with a higher risk of developmental disabilities, including Cerebral Palsy, Autism Spectrum Disorder, and Attention Deficit Hyperactivity Disorder (Schieve et al., 2016).

Furthermore, fetal growth and preterm birth have a tangible and observable physical impact on children. Together they form the leading risk factor for child stunting in developing countries, accounting for 32.5% of all stunting cases, which translates to approximately 14.4 million (12.6-16.2 million, 95% CI) cases of childhood stunting annually, including 4.7 million (4.3-5.1 million, 95% CI) in Sub-Saharan Africa alone (Danaei et al., 2016).

Prenatal heat exposure and child development

There is some evidence directly linking prenatal heat exposure to child development outcomes. Notably, Wilde et al. (2017) found that temperature increases around the time of conception and early pregnancy are associated with improved educational attainment and literacy in a six-country sample from Sub-Saharan Africa. They suggest that this effect is primarily due to fetal selection, as indicated by a higher female-to-male birth ratio following increased heat exposure early in pregnancy. Conversely, a study from rural China by Hu and Li (2019) found that higher temperatures during pregnancy, particularly in its early stages, was linked to lower literacy and educational attainment. This discrepancy may stem from methodological differences, such as variations in exposure windows and heat measurement, or it might reflect different dominant mechanisms: fetal selection in the Sub-Saharan context versus fetal growth deficits in the Chinese case. Both studies used similar estimation techniques, including time-location fixed effects (e.g., county-year, region-month). This is a representative example of the present limitations associated with this area of research – the lack of methodological commonality makes it impossible to clearly identify, let alone disentangle, channels of impact.

Other relevant research directly linking prenatal heat exposure to child outcomes includes a study from Duchoslav (2017), which finds that higher ambient temperatures during gestation were associated with reduced cooperation in public goods games among Ugandan children and adults. Randell et al. (2020) directly identify a positive correlation between temperatures *in utero*—especially during the first and third trimesters—and childhood stunting in Ethiopian children, as well as a similar link between prenatal rainfall and stunting. They propose several potential pathways for these effects, focusing on heat stress, infectious disease prevalence, agricultural productivity, and maternal time use (Randell et al., 2020).

However, a recent review by Brink et al. (2024) notes that these long-term effects of prenatal heat exposure have generally received "less attention" compared to birth outcomes. They highlight significant gaps in the literature, including the lack of studies using heat indices rather than temperature alone, which, as previously described, means that key aspects of heat exposure have been overlooked. Additionally, they argue that existing research disproportionately focuses on wealthier, cooler regions rather than lower-income, hotter areas where the impacts are likely more pronounced (Brink et al., 2024). Among the 29 studies reviewed, these authors identify evidence for negative effects of prenatal heat exposure on mental health, educational and socioeconomic outcomes, and certain health conditions. However, they also find that the quality of these studies varies widely, and warn about the possibility of a publication bias likely favouring negative impacts over null findings. Specifically, they rate the evidence quality regarding behavioural, educational, and socioeconomic outcomes as "very low".

Childcare and heat exposure

There is evidence that heat exposure during pregnancy and very early childhood affects childcare practices and, consequently, child development. Qualitative (Lusambili et al.,

2024) and quantitative (Part et al., 2022) studies from Sub-Saharan Africa indicate that mothers are less likely to practice exclusive breastfeeding during extreme heat, often supplementing breast milk with other fluids. This behaviour, largely driven by concerns about reduced milk production and child dehydration, contradicts medical advice, which advocates for exclusive breastfeeding even in conditions of extreme heat (Edney et al., 2022).

Other heat-related impacts on childcare and child health, such as infants developing skin and mouth blisters that hinder breastfeeding and reduce sleep quality, have been documented by Lusambili et al. (2024). In addition, mothers in this study reported greater fatigue, longer recovery times after childbirth, and less engagement with postnatal healthcare in high-heat conditions. Interviews conducted by the ENBEL network with mothers in rural Kenya and Burkina Faso concur with the claim that newborns exposed to high temperatures may develop heat rash and other skin issues, leading to discomfort that could decrease breastfeeding and kangaroo care (ENBEL, 2023). A recent study in Burkina Faso by Kadio et al. (2024), focusing on women's perspectives on the impacts of heat on their physical and mental health, similarly concludes that extreme heat affects women's ability to care for their children, including reduced breastfeeding and skin-to-skin contact.

Furthermore, a review by Lakhoo et al. (2022) identifies a link between high temperatures and increased infant mortality, as well as health issues like hand, foot, and mouth disease. Despite these findings, the health impacts of heat on mothers and children remain underexplored, particularly in vulnerable populations. Indeed, Lakhoo et al. (2022) conclude that there is an "obvious mismatch" between vulnerability to these effects and their coverage in the literature — their review did not find a single suitable study from Africa, the Middle East, or South America, and found little evidence describing how effects vary across socioeconomic groups. Like other authors in previous sections, these authors critique the methodological heterogeneity in this literature because of the detrimental consequences it has for the generalisability of findings, and observe a lack of evidence based on exposure indices using factors beyond temperature.

To partially address these gaps, Lakhoo et al. (2024) are currently conducting a meta-analysis using novel empirical methods, including machine learning, to examine the relationship between heat exposure and maternal and child health outcomes in Sub-Saharan Africa.

Conclusion

In the preceding sections, we have identified empirical and theoretical support for several possible pathways linking heat exposure during pregnancy to outcomes in childhood and adulthood. These pathways can be grouped into two main categories.

The first category involves direct physiological effects on the fetus during pregnancy. In broad terms, the widely proposed mechanism underlying these effects is this: increased maternal heat exposure raises heat strain, which can inhibit or alter fetal growth, and lead to higher rates of fetal loss. These changes, in turn, go on to influence subsequent child development outcomes. There is evidence supporting each part of this set of pathways – several studies have linked prenatal heat exposure to higher incidence of low birth weight, preterm birth, and stillbirth, and others have separately linked these birth outcomes to those in childhood. However, evidence studying the overall pathways (heat exposure-fetal outcomes-childhood outcomes) remains very limited.

The second category is broader and considers how heat exposure during pregnancy might impact the postnatal inputs that a child receives. Our review has identified several potential factors in this group. For example, maternal health and breastfeeding ability may be compromised by heat exposure during pregnancy, potentially affecting both nutrition and childcare quality. There are other pathways in this category not covered in detail here, because the link to prenatal heat exposure is less direct, and has little to no specific coverage in the literature. For instance, heat exposure at the time of pregnancy might reduce subsequent agricultural productivity, thereby limiting food availability and nutrition, or it could facilitate the transmission of infectious diseases. Although each of these seems likely to have lasting impacts on child wellbeing, accurately disentangling these more complex effects would require longitudinal data tracking various inputs throughout childhood. Without this, a comprehensive analysis of postnatal-input pathways remains out of reach.

Across the different pathways and topics reviewed here we found a number of clear research gaps. These can be summarised into five broad limitations: (1) A lack of studies that investigate long-term developmental outcomes beyond the perinatal period; (2) An absence of studies on long-term outcomes using heat indices, rather than solely temperature metrics; (3) Inconclusive evidence regarding critical exposure windows and thresholds for heat-related impacts; (4) Limited research in high-vulnerability settings, particularly in regions with high heat exposure, low income, and limited capacity to mitigate the effects of heat; and (5) Insufficient evidence on which pathways contribute most significantly to long-term developmental outcomes.

Although climate change, health, and child wellbeing are key issues in international policy-making, we can see from the evidence reviewed here that our understanding of the interplay between the three remains limited. In this article, we have drawn upon research at the intersection of climate science, development studies, population health and medicine, which demonstrates the need for future study built upon collaboration across these disciplines.

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