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Indoor Temperature and Energy Insecurity: Implications for Prenatal Health Disparities in Extreme Heat Events

Gabriella Y. Meltzer,[1,2] Pam Factor-Litvak,[1] Julie B. Herbstman,[2] Blair J. Wylie,[3] and Diana Hernández[4]

[1]Department of Epidemiology, Columbia University Mailman School of Public Health, New York, New York, USA
[2]Department of Environmental Health Sciences, Columbia University Mailman School of Public Health, New York, New York, USA
[3]Collaborative for Women's Environmental Health, Columbia University Irving Medical Center, New York, New York, USA
[4]Department of Sociomedical Sciences, Columbia University Mailman School of Public Health, New York, New York, USA

Background: Extreme heat events are a major public health concern and are only expected to increase in intensity and severity as climate change continues to accelerate. Pregnant people are physiologically more vulnerable to the effects of extreme heat, and exposure can induce harm on both the pregnant person and the fetus.

Objectives: This commentary argues that there is a need for greater epidemiological research on indoor heat exposure and energy insecurity as potential drivers of maternal and child environmental health disparities.

Discussion: While there is substantial evidence linking ambient (outdoor) high temperature to pregnancy-related outcomes, there is a lack of epidemiological evidence to date on pregnant people's exposure to high indoor temperature and adverse maternal and/or child health outcomes. Energy insecurity is disproportionately experienced by people with low incomes and/or people of color, and indoor temperature may play a role in shaping socioeconomic and racial/ethnic disparities in maternal and child health in the United States. Further research is needed to understand the relationship between indoor heat exposure, energy insecurity, and pregnancy outcomes in both parents and children and to inform potential policies and practices to enhance resilience and reduce maternal/child health disparities. https://doi.org/10.1289/EHP13706

Introduction

Extreme heat events, prolonged periods of abnormally hot temperatures, are the most dangerous climate-related exposures, causing more fatalities in 2021 than floods, hurricanes, extreme cold, and winter weather combined.[1,2] Research has shown that each additional extreme heat day per month was associated with 0.07 additional deaths per 100,000 in the United States from 2008 to 2017.[3] Not only can extreme heat events be fatal, but they also are associated with nonfatal, acute health incidents (e.g., dehydration, stroke) and exacerbation of chronic respiratory, cardiovascular, metabolic, and mental health conditions.[4] Extreme heat events are only expected to increase in frequency and severity as climate change continues to accelerate.[3] Given the known dangers of extreme heat events, particularly for pregnant individuals,[5] there is an urgent need for additional research to examine the implications of both outdoor and indoor extreme heat exposure for maternal/child health disparities.

Extreme Heat and Pregnancy

There is a growing body of research on the deleterious effects of exposure to extreme ambient heat during pregnancy.[5] These include adverse birth outcomes such as preterm birth,[6] stillbirth,[7] congenital anomalies,[8] and low birthweight,[9] as well as adverse maternal health outcomes like hypertension,[10] preeclampsia,[11] gestational diabetes,[12] hemorrhage,[13] and infections.[14] Researchers have proposed several biological mechanisms through which extreme heat exposure can induce harm on both mother and fetus. First, pregnant people are thought to be physiologically more vulnerable to the effects of extreme heat; their baseline core body temperature is higher due to greater body fat and higher fetal metabolic rate, and their heat loss capacity from sweating is lowered as a result of a decreased ratio of surface area to body fat.[14,15] If ambient temperature exceeds maternal core body temperature, thermoregulatory processes developed during pregnancy may become overwhelmed and the body may respond with cutaneous vasodilation and sweating above and beyond the normal changes of pregnancy, which, in turn, can decrease blood flow through the placenta and may lead to dehydration.[14,15] When the pregnant body becomes dehydrated, the endocrine system releases prostaglandins, antidiuretic hormone, and oxytocin, which decreases uterine blood flow and can trigger premature contractions and labor.[14,15] Preterm labor can also be instigated by the inflammatory release of endotoxins, cytokines, cortisol, and adrenaline.[14,15] Acute heat stress can damage placental cells and reduce the placental delivery of oxygen and nutrients to the fetus.[16] It also disrupts genetic activity involved in protein folding during first trimester organogenesis, potentially leading to congenital abnormalities or stillbirth later in the pregnancy.[14,15] Extreme heat exposure has been shown to negatively affect glucose metabolism and increase insulin resistance in animals and has been associated with gestational diabetes in human studies.[12,14,15,17]

Discussion

The Importance of Indoor Temperature

While there is substantial and growing data linking ambient, or outdoor, high temperatures to pregnancy-related outcomes, there is no epidemiological evidence to date on pregnant people's exposure to high indoor temperature and adverse maternal and child health outcomes.[18,19] We posit that unlike outdoor temperatures, there is a lack of accessible secondary data on indoor temperatures, and it is more logistically challenging to collect primary data on people's indoor environments. This is problematic because indoor temperature is just as emblematic of people's lived experiences during periods of extreme heat, evidenced by the fact that North Americans and Europeans spend over 90% of their time indoors.[20] In fact, studies in diverse geographic contexts have demonstrated that

Address correspondence to Gabriella Y. Meltzer, Department of Epidemiology and Environmental Health Sciences, Columbia University Mailman School of Public Health, 722 W. 168th St., New York, NY 10032 USA. Email: gm3085@cumc.columbia.edu

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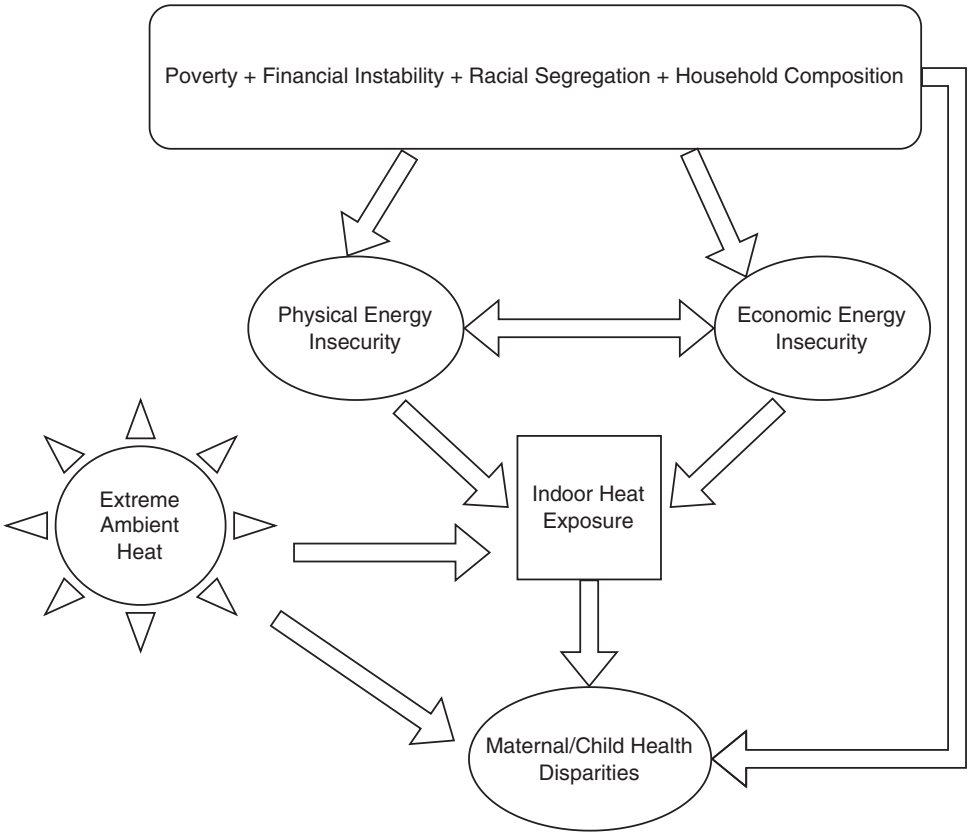

Figure 1. Conceptual framework on impact of energy insecurity on heat exposure and maternal and child health disparities. This schematic shows how structural inequities related to housing shape physical and economic energy insecurity, which, in turn, influence indoor heat exposure. Indoor and ambient heat exposure operate jointly to affect maternal and child health disparities.

indoor temperatures oftentimes exceed those outdoors.[21–24] Public health literature has demonstrated the association between indoor heat exposure and acute respiratory morbidity, mental health and cognition, physical functioning, blood pressure, blood glucose levels, heat stroke, and influenza transmission.[18,19] While these studies have been done in population groups at other sensitive periods of the life course (e.g., older adults at home or in nursing homes and adolescents in classrooms),[21,25] none have examined the association between indoor heat exposure during pregnancy, to our knowledge.

The authors hypothesize that indoor temperature—especially in the home—is equally consequential for maternal and child health and wellbeing in the United States and other high-income nations as ambient temperature. Therefore, it is imperative to take into account the physical and economic energy insecurity that jointly influence thermal comfort in the home.[26] Determinants of physical energy insecurity that shape household heat conditions include the house, mobile home, or multi-unit building's energy efficiency, ventilation, availability of air conditioning units, ability of the power grid to handle high demand, and, in the case of rental units, the degree of control that tenants vs. landlords have over the housing unit's temperature.[26,27] Even if physical conditions are adequate, utilities such as air conditioning may be prohibitively expensive leading to economic energy insecurity, potentially forcing families to choose between paying for food, rent, or energy, otherwise known as the "heat or eat" dilemma.[28] It is also important to note that indoor extreme heat exposure occurs not only at home but can also be an occupational hazard if workplaces and modes of transportation for commuting are not sufficiently cooled or ventilated.[29–31] This is especially the case for those in low-wage, nonclerical industries involving manual labor in settings such as factories, warehouses, and restaurants.[32]

Energy Insecurity as a Risk Factor for Maternal/Child Health Disparities

Physical and economic energy insecurity are disproportionately experienced by low-income and/or communities of color.[33] For example, in the United States, African Americans are more likely than white individuals to live in energy inefficient homes characterized by "structural deficiencies, outdated appliances, and faulty energy systems."[34] Compared to the average household, households near or below the federal poverty line are most likely to spend at least 10% of their income on energy expenses, and African American households experience economic energy insecurity at the highest rate.[28] From a neighborhood standpoint, low-income, predominantly non-white neighborhoods tend to have less tree canopy and green space and greater impervious surface and building density—all of which contribute to higher surface temperatures.[35] Even when accounting for these built environment conditions, measuring ambient temperature alone only takes the neighborhood context into account, ignoring far more proximal and inequitable physical and economic determinants of indoor home temperature.

With that in mind, we suggest that indoor heat may play a role alongside ambient heat, which has yet to be empirically examined in shaping maternal and child health racial/ethnic disparities in the United States. Maternal mortality rates are over two and three times higher among African American and American Indian/Alaska Native women than white women, respectively.[36] These groups also bear a disproportionate burden of complications such as preterm birth and low birthweight.[36] In addition, infants born to African American, American Indian/Alaska Native, and Native Hawaiian/Pacific Islander mothers are at least twice as likely to die from congenital anomalies or sudden infant death syndrome as compared to non-Hispanic white mothers.[36] It is possible that

disproportionate exposure to extreme heat due to inequitable physical, economic, and neighborhood housing conditions could contribute to these maternal and child health disparities (Figure 1).

Future Directions

Further research is needed to understand the relationship between indoor heat exposure, energy insecurity, and pregnancy outcomes, especially as climate change causes dangerous heat waves to increase in frequency and severity.[24] Despite the logistical challenges they pose, epidemiological data collection methods using personal, in-home, and/or workplace temperature and humidity monitors could be informed by prior studies that have evaluated the association between indoor air pollution and pregnancy outcomes or by community engaged methods employed by environmental justice researchers.[37–39] Equitable physical, economic, and contextual housing conditions are necessary to ensure pregnant people's climate resiliency, particularly in those most vulnerable on the basis of socioeconomic status or race/ethnicity.[40] The authors propose that research on the association between indoor heat exposure, energy insecurity, and pregnancy could provide an evidence base to inform potential policies and practices that can enhance resilience to extreme heat and reduce maternal/child health disparities. These could include improved guidelines surrounding indoor heat exposure for pregnant people issued by medical providers, policymakers, and public health professionals; energy assistance programs or provision of supplemental air conditioning for pregnant people and new parents; or special protections for pregnant people to avoid disconnections by utility companies.

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