EARLY CHILDHOOD SCIENTIFIC COUNCIL ON EQUITY AND THE ENVIRONMENT

Extreme Heat Affects Early Childhood Development and Health

WORKING PAPER 1

Center on the Developing Child
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EARLY CHILDHOOD SCIENTIFIC COUNCIL ON EQUITY AND THE ENVIRONMENT

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Devon Payne-Sturges, DrPH
Associate Professor, Maryland Institute for Applied Environmental Health, University of Maryland, School of Public Health

Natalie Slopen, ScD
Assistant Professor, Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health

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The Early Childhood Scientific Council on Equity and the Environment, housed at the Center on the Developing Child at Harvard University, is a multi-disciplinary, cross-organizational collaboration committed to improving our understanding of how influences from the broader environment affect early childhood development. Established in 2023, the Council aims to leverage both scientific and community-informed perspectives to help policymakers and leaders across a range of sectors understand and mobilize around a prenatal and early childhood perspective that is rooted in working toward fairness of place for all children, with particular attention to communities of color and people living in poverty. For more information, go to www.developingchild.harvard.edu.

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THE ISSUE:

Extreme Heat Affects Early Childhood Development and Health

This working paper is the first in a series focusing on the ways that environmental conditions shape young children's development. Heat is just one component of a set of interrelated conditions that affect how children's bodies and brains develop. This working paper offers a summary of current knowledge about how heat impacts developing biological systems.

Personal experience, common sense, and science all confirm that temperatures are rising across the United States and around the world. Record-setting heat waves are occurring with greater frequency and lasting longer than ever before.[1] Average temperatures around the world continue to rise.[2] The dangers of excessive heat to older people and those with heart and lung conditions are well known, but the effects of heat during pregnancy, infancy, and childhood get less attention. These effects are significant, including low birth weight and prematurity, learning loss during the school years, and heat-related illness and death.[3] Excessive heat can impact young children's development and health both in the moment and across the lifespan, so implementing effective strategies to reduce exposure to extreme heat benefits children, families, and communities now and in the future.

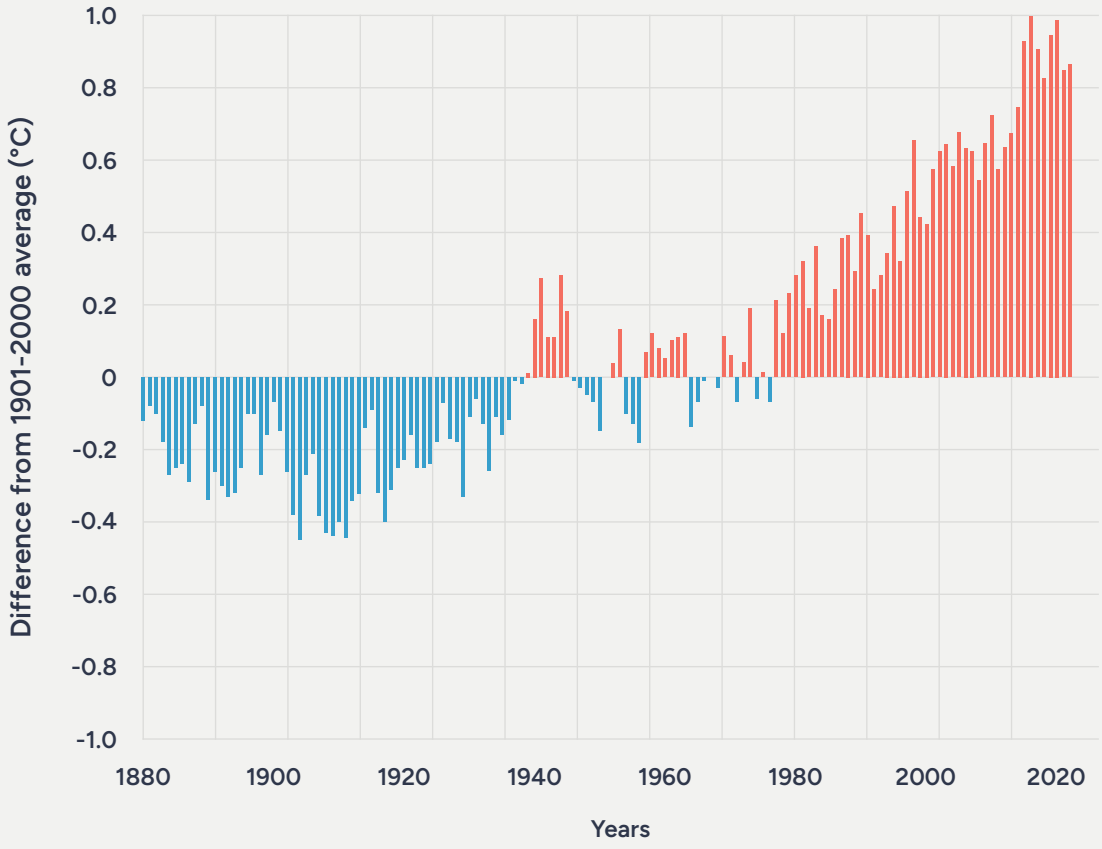
Extreme heat affects infants and young children more than most adults because their smaller bodies heat up more quickly, and they have less capacity to release heat via sweating.[4-6] The biological systems that regulate body temperature in infants and young children are less developed and, therefore, less efficient.[7] Infants and young children also can't seek out cooler environments or get water to drink without relying on adults.[5,6] Children and adolescents with chronic health conditions, such as asthma, obesity, or diabetes, are even more susceptible to heat-related illnesses.[3,4]

Practical, actionable solutions exist to prevent or minimize these impacts, and many communities, organizations, and nations have already begun implementing them to good effect.[8] Because all children should have the opportunity to thrive, we first need to understand how extreme heat affects children and then determine how best to take action.

Extreme Heat Affects Us All

Increasing temperatures and heat waves affect every region on Earth, just as they affect every cell and organ system in the body. Excessive heat is when temperatures are significantly higher than normal for any given location, so people who live in typically cool and dry areas are affected as much as those who live in typically hot and humid environments. Humans have successfully adapted to a wide range of climates, and the thresholds of temperatures we can withstand vary according to what we are accustomed to—but there are limits to our tolerance.[9] The human body is tuned to maintain a core temperature at a near-constant level regardless of the temperature outside, but our biological temperature control systems can be overwhelmed.[10] Although it varies by individual and region, there are climatic

Global Average Surface Temperature



Based on data from the National Centers for Environmental Information, this figure from the National Oceanic and Atmospheric Administration shows yearly surface temperature compared to the 20th-century average from 1880–2022. The blue bars indicate cooler-than-average years, and the red bars show warmer-than-average years.[90]

conditions beyond which our bodies simply cannot cool themselves sufficiently.[9]

The human body responds to excessive heat primarily by (1) redistributing blood flow toward the skin so heat can transfer out of the body and into the environment and (2) sweating, which evaporates on the skin, bringing body heat down. The blood flow cooling method is especially important in young children. As long as the air temperature is cooler than the body's temperature, heat dissipates through the skin to the outside environment.

When temperatures rise, the brain regulates these physiological responses, with additional input from temperature-sensitive nerve cells in the skin and throughout the body.[4] Cells also produce heat shock proteins, which act as "chaperones" that stabilize the structure of other proteins that high temperatures could damage. Every cell in our body contains heat shock proteins. They protect a variety of other proteins that are critical to life, including hemoglobin, which carries oxygen to our cells.[11]

Over short periods of time, heat shock proteins are effective and helpful, but when temperatures stay too high for too long, they lose their ability to function, and the proteins they protect start to break down.[9,11,12] This can have a variety of long-term impacts on health, including activation and misdirection of the immune system against proteins that have broken down, leading to increased susceptibility to infections and a decreased response to vaccines.[13] There is a cascade of reactions and consequences in key biological systems connected to these cooling responses:

Brain—Inside the brain, the hypothalamus acts as a thermostat for the entire body, sensing temperatures and reacting to keep core temperatures in a healthy range. When temperatures rise, the hypothalamus sends signals throughout the body to trigger cooling responses, such as increased sweating and blood flow toward the skin's surface. If continuous, high temperatures prevent the hypothalamus from shutting off these cooling responses—or if high temperatures combined with high humidity make them ineffective—excessive sweating can lead to dehydration, which affects the functioning of the brain and other organ systems.[14] In addition, the brain "runs hot"—the neurochemical reactions involved in cognitive functioning generate heat. Because brains can't sweat, they rely on increased blood flow to cool down. Under normal conditions, the circulating blood is cooler than the brain, allowing the brain to cool down and heat to transfer out. However, when the outside temperature is too hot, and the body cannot release heat as effectively, the brain cannot cool to its normal range.[15] In an overheated brain, the lining of the membranes in nerve cells can be affected, which can cause neurons to fire more slowly or, in the case of very high temperatures, to go silent.[16-18] This may lead to slowed cognitive and emotional functioning—particularly attention, memory, and information processing.

Immune System—When heat shock proteins break down from prolonged high temperatures, the body identifies them as foreign invaders and sends immune cells to fight them.[12] This redirects the immune system from its primary job—making antibodies to fight an infection or a virus. Having fewer antibodies also reduces the ability of the immune system to repel many insect-borne diseases, such as West Nile and Lyme disease, that are now reaching larger areas of the United States due to warmer temperatures.[19] Another important part of the immune response is inflammation, which prepares the body to heal potential wounds. A prolonged state of alert for the body's healing systems can put these powerful inflammatory substances in contact with the body's organs, which can lead to increased risk for a wide range of health conditions, from asthma to heart disease to diabetes.[20]

> **Over short periods of time, heat shock proteins are effective and helpful, but when temperatures stay too high for too long, they lose their ability to function, and the proteins they protect start to break down.**

Skin and Gut—In response to heat, pores in the skin open to allow more sweat to pass through and evaporate, increasing the body's ability to cool itself. Our gut, which contains a wide range of bacteria, is also porous, but it has a lining that functions to keep those bacteria inside the intestines. In response to extreme heat, this lining can become leaky, allowing bacteria to pass out of the gut and into other parts of our bodies. When these changes happen for extended periods of time, it can increase the likelihood that harmful bacteria and toxins will reach the body's vital organs via the circulatory system. This "invasion," in turn, activates the immune system and systemic inflammation even further.[21]

Heart and Other Muscles—In response to excess heat, the heart rate increases to send more blood to the skin, releasing the body's core heat into the environment. Consequently, less blood is sent to the muscles, which can constrain muscle growth, cause muscle fibers to break down, and contribute to kidney dysfunction. The heart itself is a muscle that can fatigue through overwork when high temperatures are sustained, contributing to high rates of heart failure during heat waves.[22] When muscle breakdown occurs due to excessive heat, the muscle tissue can die, releasing proteins into the bloodstream that can cause irregular heartbeat, kidney damage, and seizures.[23]

Dehydration—Water is essential for all systems in the body to function properly, and during heat events and exercise, it is necessary to replenish the water lost through sweat. While serious harm from extreme heat, including heat stroke, can occur without dehydration, not having enough water in the system thickens the blood, which can lead to increased blood clotting and heart failure from blockages in the arteries. Insufficient water can also lead to kidney dysfunction, muscle cramps, mental disorientation, and low oxygen levels in the blood. Infants are particularly at risk, as they cannot replace fluids themselves.[22]

When sustained over time, all these responses can lead to what is known as "heat stress." When this happens, the body begins to break down and critical functions shut down, increasing the likelihood of damage to the heart, lungs, and kidneys as well as the risk of heat-related death.[22] Heat stress can be caused by several days with air temperatures significantly above the local average high temperatures.[24] Heat stress can lead to heat stroke (the inability of the body to cool down, which can be fatal), heat exhaustion (with symptoms including headache, nausea, and fatigue), and the breakdown of muscle tissue (which can cause organ failure and death).[3] While some effects of heat stress may be immediately apparent, there may also be effects—like cognitive and organ dysfunction—that can persist for years, putting those who experience heat stress at two to three times greater risk of death for decades after experiencing extreme heat.[4]

The effects of heat are influenced by a range of factors that, when combined, influence how children are affected.[22] Chief among these factors is socioeconomic inequalities, which disproportionately impact marginalized racial and ethnic groups. These communities frequently confront a spectrum of structural, political, social, and economic barriers that have systematically restricted access to essential resources. Despite the wide array of living conditions and experiences, intersections among cultures, and socioeconomic statuses within groups, in general, health risks in the United States are significantly greater for those most directly affected by the legacy of discriminatory policies that shape the environments within which people live.[25]

Living in places that have fewer resources and opportunities makes it more difficult to get relief from the heat. There is less air conditioning, fewer public cooling spaces, a lack of clean drinking water, and a greater likelihood of living in housing and neighborhoods that trap rather than mitigate heat (for example, with lots of blacktop and few green spaces).[26] This contributes to the significantly increased risk of physical and mental illness, preterm birth, and death for people of American Indian, Native Alaskan, Black, and Latinx descent in the United States as a result of extreme heat exposure.[27] Community efforts led by marginalized groups to build access to opportunity, develop infrastructure, and mobilize local responses to extreme heat are gaining momentum in reversing these inequities.[28]

Community-Driven Solutions

In July 2017, 15 teams of community and student volunteers spread out through Richmond, Virginia, with simple, hand-made devices designed to measure air temperature and mark time and location. Collecting more than 60,000 temperatures, this effort was the beginning of Richmond's community-driven heat-mapping project that showed differences of up to 16°F across Richmond's neighborhoods—one area might register 87°F, while another neighborhood just across town registered 103°F. Researchers then compared data and saw that Richmond's hottest neighborhoods had the highest levels of pavement, the lowest levels of tree canopy, the lowest incomes, and the highest numbers of health emergencies requiring first responders.[29] These insights led to community action: Richmond developed a Climate Equity Index in 2020 to pinpoint neighborhoods at greatest risk and help decision-makers focus on key factors to address.[30] Data from the index informed "RVAgreen 2050," an equity-oriented environmental action plan that calls for cooling strategies such as increasing tree canopy, installing shades at bus stops, depaving (replacing paved surfaces with vegetation or more permeable pavers or asphalt), installing cool pavement (paving materials that have been modified to remain cooler than conventional pavements), and utility bill assistance.[31] The index the Richmond group created also provides tools to map the locations where cooling centers and food assistance sites are most needed. City officials adopted a community engagement process that identified local priorities and centered equity; for example, the city's lower-income south side was able to convert 36 unused acres into green spaces.[32]

Heat Has Especially Powerful Effects on Babies and Young Children

In times of extreme heat, normal physiological changes that occur during pregnancy can create additional risk. The body already produces more heat during pregnancy because of the increased metabolism needed to support fetal development and the strain from increased body mass.[33] There are protective adaptations during pregnancy to compensate for these changes, such as a lower threshold for sweating and an increase in blood flow to the skin. But extreme heat can overwhelm these adaptations, and there are several mechanisms by which extreme heat may lead to preterm birth. High temperatures may result in reduced blood flow in the placenta, dehydration, and inflammation, which can trigger preterm birth.[34] There is evidence that during times of high temperatures, there are increased rates of stillbirth[35,36] as well as more premature and lower birth weight babies, all of which are linked to greater risk of a range of poor outcomes later in life, including impaired cognition, reduced growth, and chronic health issues such as cardiovascular disease and diabetes in adulthood.[37-43]

Heat stress can also affect young children in many ways, in part because their bodies respond differently to extreme heat than adults. For example, children do not sweat as much as adults, particularly in extreme heat, which limits a key method the body uses to cool itself.[6] This is especially true for infants and toddlers. If the body is unable to cool itself properly, excess heat can lead to muscle breakdown, kidney failure, seizure, coma, or even death in extreme

cases.[3] In addition to these immediate effects, heat can disrupt development through three distinct pathways:

Learning loss—Heat is linked to slower cognitive function and reduced concentration ability.[11] One analysis of school-age children in the US, England, Sweden, and Denmark calculated that the temperature for optimal concentration is 72˚F (22˚C) or lower. Student performance on psychological tests and school tasks can be expected to increase on average by 20% if classroom temperatures are lowered from 86˚F to 68˚F (30˚C to 20˚C).[44] Conversely, studies show that school performance decreases as temperatures rise. In New York City, for example, learning losses increased by up to 50% when school-day temperatures went above 100˚F compared to days above 90˚F. In addition, the learning loss from extreme heat events can be lasting: Hotter school days two, three, and even four years prior to a test correlate to lower scores.[45] Learning loss may occur because heat's effects on the brain can produce slower reaction times and an inability to focus. Heat's effects on sleep (see below) can also lead to cognitive disruption and learning difficulties in early childhood.[46] Learning in a hot classroom can lead to both students and teachers feeling unmotivated, distracted, or irritable. And, if schools are uncomfortably hot, students or teachers may intentionally miss or avoid school.[3] Fortunately, air conditioning and other cooling methods, such as heat pumps, appear to offset most of the disruptive impacts of heat events on learning,[47] pointing to the effectiveness of cooling as a practical, cost-effective solution that is already widely available in many states, but unfairly distributed by income, ethnicity, and location.[47,48]

The brain detects extreme heat as a threat to well-being, which activates the stress response system. During pregnancy and early childhood, excessive activation of this system can disrupt development of emotional regulation circuits.

Sleep quality—Getting enough good-quality sleep is essential for healthy growth and development. A growing body of evidence shows associations between less sleep in infancy and childhood obesity, and sleep habits in childhood may impact weight well into adulthood.[49-52] This is likely related to sleep deficits and disturbances disrupting the hormones that are important in feelings of hunger.[53] Sleep deficits in infancy also increase the likelihood of experiencing emotional and behavioral challenges in early childhood, disrupted language development, and reduced problem-solving skills.[54,55] Temperature plays an integral role in sleep quality. As the body prepares for sleep, core body temperature typically decreases, facilitating the onset of sleep. External heat can prevent this, leading to poor sleep and potentially negative outcomes for children, as outlined above. During the 2022 heat wave in the UK, researchers studied the impact of unusually high temperatures on infants' sleep. They found that when temperatures ranged from 96˚F to 102˚F, infants took longer to fall asleep, had less total sleep, had less efficient sleep, and had more fragmented sleep, and parents' visits were more frequent during the night. Following the heat wave, infant sleep patterns rebounded, demonstrating that the negative impacts of one heat wave are not permanent and can be quickly remediated by reducing infants' exposure to heat in the future.[46]

Mental and behavioral health—Because children's brains and bodies are developing rapidly and are highly sensitive to their experiences, early childhood is a period where threats to well-being can have long-lasting effects on mental health.[56] Because of this, treatment and prevention efforts in the early years can have much larger effects on children's long-term psychological health and well-being than efforts that begin later.[57] The brain detects extreme heat as a threat to well-being, which activates the stress response system.[58,59] Excessive activation of the stress response system during pregnancy and in young children can disrupt the development of healthy emotional

regulation circuits in the developing brain of a child or fetus.[60] Excessive heat also increases violent crime, conflict, and suicide through a combination of environmental factors—more people are outside—and biological changes—heat disrupts the hormones and neurotransmitters that stabilize moods, leading to increased irritability and aggression.[61-63] Experiences of violence are potent activators of the stress response during pregnancy and in young children and can cause long-lasting trauma and a decreased sense of physical and psychological safety.[57] Because young children are so powerfully affected by the environments and relationships around them, efforts that reduce or ameliorate the effects of heat in a community can also mitigate factors that contribute to the development of mental and behavioral health problems in children.[64-66] For example, decreasing heat islands in cities may allow more people to exercise outdoors in their community, positively affecting the physical and mental health of both children and their caregivers.

Heat Does Not Act Alone

Many factors, including economic status, nutrition and diet, living conditions, geographic location, and stage of development, shape the impact that excessive heat has on a child's health and development.[19] For example, an infant or young child whose family lives in a neighborhood with few options for cooling, poor air quality, little access to healthy foods, and few resources and economic opportunities will likely be more affected by extreme heat than a child whose community provides more resources and opportunities. While heat affects everyone, it also amplifies the effects of systemic inequities in housing, neighborhood density, community infrastructure, and economic opportunity, contributing to an unequal burden of dangerous conditions for families from marginalized groups and with lower incomes.[26] Heat also affects the frequency and severity of life-altering natural disasters, including wildfires, floods, and hurricanes, the ability to work and play outdoors, air quality, the availability of drinking water, and the nutrition levels of key crops—all of which also affect child health and development. Yet all of these conditions can be modified to improve a community's resilience to excessive heat, thereby better protecting children from its harmful effects:

While heat affects everyone, it also amplifies the effects of systemic inequities in housing, neighborhood density, community infrastructure, and economic opportunity, contributing to an unequal burden of dangerous conditions for families from marginalized groups and with lower incomes.

Air quality—As we have seen in recent years, smoke from wildfires—and the poor air quality that can last for weeks or even months after a fire—threatens children and adults, even at a considerable distance from the fire's location.[3] As noted above, these events are made more frequent and dangerous by increasing heat, and they can have both short- and long-term effects on children's health. The immediate connection between wildfire smoke and increased hospital visits for respiratory diseases like asthma is clear and straightforward, but smoke can also have lasting, damaging effects on pregnancy outcomes. Increased air pollution from projected increases in wildfire activity may result in more adverse birth outcomes. For example, an increase of just 7°F (4°C) in global temperatures is predicted to cause a 92% increase in premature births, meaning

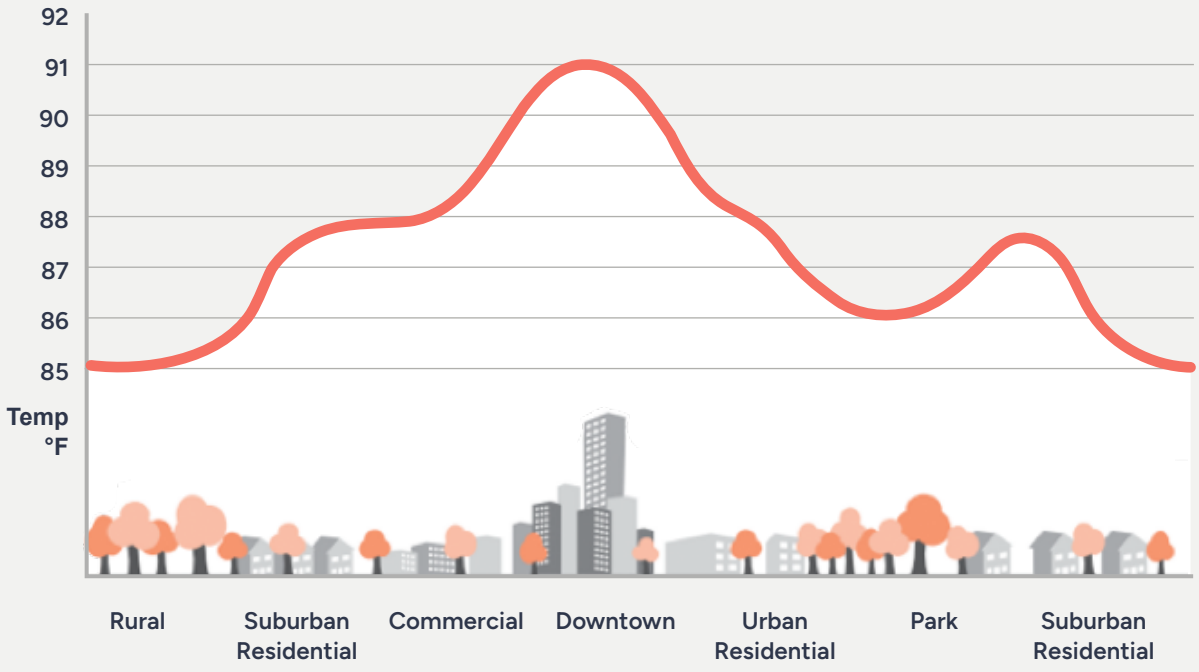
an additional 13,600 premature births every year due to wildfire smoke exposure.[3,67] And smoke is not the only way heat affects air quality. During times of hot temperatures, the heat and sunlight essentially cook the air, releasing chemical compounds[68] like ozone (a cause of life-threatening breathing problems) that stay trapped in the air at normal temperatures.[69] Hot and still air also prevents particulate matter from smoke and fossil fuel emissions from dissipating, which is linked with increased severity and frequency of asthma, other respiratory diseases, cancer, and skin rashes in children, as well as preterm birth, low birth weight, and birth defects after exposures during pregnancy.[3] It is no coincidence that the neighborhoods with the highest temperatures also have the most polluted air and the highest rates of childhood asthma.[70-72] These findings reinforce the critical importance of reducing emissions from fossil fuels and reducing exposure to heat to provide all children with a chance to thrive.

Nutrition—As fetuses, infants, and young children are rapidly developing, they have greater nutritional and fluid requirements than adults and are therefore more sensitive to disruptions in their food and water supply.[7] Not only do young children have little control over what, when, and how much nutrition and water are available to them, but local and global supplies of nutritious foods and water are also highly affected by extreme heat. The dwindling availability of fresh, clean drinking water around the world due to heat-driven drought has been well chronicled, but the effects of heat on agriculture and food supplies are often overlooked. The ability to grow crops is damaged by scorching heat, dry reservoirs, and severe storms, including hurricanes that are growing more frequent and more intense due to rising ocean temperatures.[73] But heat stress also has negative biological effects on plants themselves, affecting photosynthesis, growth, reproduction, and susceptibility to bacteria, parasites, and viruses. Excessive heat decreases the nutritional value of cereal grains and the size of soybean and wheat harvests. Heat also affects livestock in myriad ways. Heat stress decreases animal growth and reproduction rates, as well as milk and egg production, and the 2003 heatwave in Europe caused a 24% increase in cattle deaths.[22] All of these disruptions in the global food chain directly impact the cost and availability of nutritious food, with the greatest impacts on those who have the least access to begin with. For example, in the United States, neighborhoods that are predominantly populated by Black and Hispanic people have the least access to affordable, healthy foods and the highest rates of food insecurity.[74-76] Food insecurity is also twice as common among American Indians and Alaska Natives compared to Whites.[77] Because access to nutritious food is already more difficult in these communities than in other places, heat-related disruptions to the food chain affect these communities more severely.

Structural Disadvantages—All children face risks from excessive heat, but these risks and their impacts are not evenly distributed. Lower-income countries are more likely to experience the life-threatening effects of an overheated climate, and current global power structures make it challenging for these countries to influence and drive change at the international level.[78] Within the US, some communities—even within the same region—are not only cooler than others but have more (and easier) access to cooling methods, such as air conditioning, green spaces, and swimming pools. The impact of heat is greatest in low-income communities of color,[25] where decades of discriminatory zoning and lending practices known as "redlining"—in which federally drawn maps restricted real estate investments in neighborhoods outlined in red, largely due to their racial and ethnic makeup—led to the creation of urban heat islands dominated by heat-trapping asphalt, densely concentrated buildings,

traffic, industry, and highways.[7,72,79] Multiple studies show that nearly all US neighborhoods that were subject to redlining are hotter today than non-redlined neighborhoods[72] and have higher levels of air pollution.[80] These neighborhoods also tend to have less access to ways of reducing children's exposure to excessive heat due to systematic underinvestment in infrastructure and economic opportunities. For example, lower-income students are more likely to be in schools without adequate air conditioning than higher-income students, and Hispanic and Black households are less likely to have access to air conditioning compared to white households.[81] Rural areas are not immune to inequities: More than half of rural US counties have no hospital obstetric services, and the odds of having no local health services for pregnancy and delivery are greatest in lower-income rural counties with more Black women of reproductive age.[82] Having to travel long distances to obstetric care for heat-related pregnancy complications likely contributes to higher rates of maternal death, infant death, and childbirth challenges in rural areas.[83] Documented inequities like these offer guidance for prioritizing heat-reducing measures where they will have the greatest impact on those with the greatest need.

Urban Heat Island Profile



This illustration shows how temperatures can become elevated in urban heat islands, in contrast to areas with more green space and less density of buildings and heat-trapping surfaces.[84]

Effective Strategies Can Create a Multiplier Effect

Practical solutions are being implemented in many parts of the world to mitigate climate change, slow the heating of our environment, and provide new ways of cooling our communities. Such strategies include a wide range of policies and private-sector actions that facilitate a shift from fossil fuels to renewable energy sources, increase energy efficiency, boost natural carbon sequestration, improve access to clean water and food supplies, protect against extreme weather events, expand the use of new cooling technologies, and address long-standing inequities in access to resources and opportunity.[7]

Because the effects of climate change are so interrelated, all efforts to address its root causes—and inequality more broadly—will boost the impact of efforts to mitigate the effects of extreme heat and contribute to improving children's health and well-being.

Because the effects of climate change are so interrelated, all efforts to address its root causes—and inequality more broadly—will boost the impact of efforts to mitigate the effects of extreme heat and contribute to improving children's health and well-being. Every little bit helps. Policies that target emissions, for instance, can both benefit children's health and be cost saving. As just one example, the Regional Greenhouse Gas Initiative—a cooperative effort among twelve states in the northeastern United States to reduce carbon dioxide emissions from power plants—is estimated to have prevented more than 16,000 cases of respiratory illness, 537 new cases of asthma, and other illnesses in children, with substantial cost savings in five years.[85]

In short, strategies that address high temperatures and other aspects of climate change are also strategies that promote the healthy development of children.

The harmful effects of excessive heat must be addressed through strategies directed at three levels:

1. Immediate actions to reduce the harm from extreme heat events;

2. Adapting our services, systems, and infrastructure to be better positioned to withstand increased heat; and

3. Addressing the root causes behind our rapidly heating planet.

Solutions at each level can be implemented through local, county, state, and federal policy, as well as social services, education, and health care. This must be done in consultation with local communities and leaders to address local needs most effectively. Local leadership is key: While efforts to address the root causes of climate change can and should be undertaken at the national and global level, a community's residents and leaders best know their greatest needs and challenges. Bringing air conditioners to a community without reliable access to the power grid, for example, or planting trees without considering future costs to a community when other forms of shade and cooling may be preferable, are just two examples of well-intentioned but misguided interventions imposed from outside rather than driven by a community.

To address the effects of excessive heat on children, policymakers and community leaders can learn from a range of practical strategies and approaches already demonstrating positive impact

in communities throughout the country and the world (see *Resources for Taking Action* for specific examples):

Consider where people spend time during pregnancy and childhood. Childcare and preschool programs, K-12 schools, summer and after-school programs, recreational sports, and homes with (or expecting) young children are all places that should be evaluated for their ability to protect people during pregnancy and childhood from exposure to excessive heat and provide what they need to withstand it, such as clean drinking water, nutritious foods, and shade. Ensuring cooling options are available during pregnancy should be considered integral to prenatal care.

Improve structural cooling options. The architecture of new buildings, retrofitting of older buildings, and urban planning can be done in a way that reduces heat and makes more efficient use of energy. Many new building materials and power sources, such as "cool pavement" and "cool roofs" with white, reflective, or permeable surfaces, can save money and lives.[86] Urban greening campaigns that increase tree canopies and surfaces covered with vegetation can decrease air temperatures and provide shade. Public access to clean drinking water and cooling shelters placed within communities (broadly advertised, including in clinics and hospitals) can better protect people from the effects of extreme heat.[22]

Install air conditioning and other cooling mechanisms. According to the US Environmental Protection Agency, more than $13 billion is lost per year in lower future earnings due to learning losses from school days that are just 7˚F higher than current averages. Yet, the annualized cost of installing and maintaining HVAC systems in all US public schools would be less than one-third of that amount.[3] Some states offer subsidies on air conditioning to low-income residents through the federal Low Income Home Energy Assistance Program (LIHEAP).[87] And a range of less-expensive and less power-demanding solutions also exist, from heat sinks (which pump heat underground) to "swamp coolers" (which use evaporation to cool air).

Provide support for affordable, reliable access to the power grid, with particular emphasis on power from sustainable sources. During the June 2023 heat wave in Texas, where temperatures reached 118˚F, recent investments in solar energy provided up to 15% of the state's power needs at critical times of the day, preventing wide-scale emergency blackouts.[88] Getting an air conditioner is no help if it can't be powered or if power is unaffordable. In some areas, pediatricians are helping families document the medical necessity of maintaining access to utilities; health insurance may even pay for utility bills in some states.[89] LIHEAP's federal Cooling Assistance Program is also available to help those with low incomes pay energy bills.[87]

Develop heat action plans. Communities and healthcare systems can come together to build community resilience. Heat action plans coordinate local government response with other agencies, healthcare facilities, and community organizations.[73] For example, health systems can build collaborations to develop local heat response plans that map areas of greatest exposure and incorporate community-derived knowledge about attitudes and practices among the most at-risk members of the community. For instance, community partnerships may identify "heat champions"—respected individuals in the community who can share information about risks and resources during heat waves.[28]

Resources for Taking Action

Children's Climate Risk Index, United Nations Children's Fund (UNICEF)
Global geographical data on the nature and scope of risk to the world's children from the effects of climate change.
unicef.org/reports/climate-crisis-child-rights-crisis

Heat-waves: risks and responses
World Health Organization report reviews knowledge about the effects of heat waves and makes recommendations for preventive action, including heat health-warning systems, urban planning, and housing design.
who.int/publications/i/item/9789289010948

Intergovernmental Panel on Climate Change
"Climate Change 2023: Summary for Policymakers" provides a range of adaptation, mitigation, and near-term actions to reduce the effects of climate change worldwide.
ipcc.ch/srccl/chapter/summary-for-policymakers/

National Center for Medical-Legal Partnerships
Helps medical professionals address legal issues, including documenting the medical necessity of heat-related utility access.
medical-legalpartnership.org/

National Institute of Environmental Health Sciences
Coordinates solutions-focused research to reduce climate change's health effects and offers educators Climate Change and Human Health Lesson Plans. https://niehs.nih.gov

Smart Surfaces Coalition
Information, tools, and initiatives to help cities incorporate reflective (cool) roofs and pavements, porous pavements, green roofs, and more "to enable cities to thrive despite climate threats, save cities billions of dollars, create jobs, decrease heat, reduce flood risk, slow global warming, and improve city livability, health, and equity."
smartsurfacescoalition.org

US Climate Resilience Toolkit
Compiles tools, information, case studies, and subject matter expertise from the US federal government to help decision-makers identify local climate threats and vulnerabilities and reduce risks.
toolkit.climate.gov

US Environmental Protection Agency

- "Climate Change and Children's Health and Well-Being in the United States" offers a range of information, research, and solutions.
  epa.gov/cira/climate-change-and-childrens-health-and-well-being-united-states-report
- "Heat Island Cooling Strategies" provides information about how communities are taking action to reduce excessive heat through vegetation, green and cool roof installation, cool pavements, and smart growth. https://www.epa.gov/heatislands/heat-island-cooling-strategies

US Global Change Research Program
Collaboration among 14 federal agencies to provide a gateway to authoritative science, tools, and resources to help people and organizations across the country manage risks and respond to changing environmental conditions.
globalchange.gov

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50 Church Street, 4th Floor, Cambridge, MA 02138
617.496.0578
www.developingchild.harvard.edu