TECHNICAL REPORT

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

Climate Change and Children's Health: Building a Healthy Future for Every Child

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Observed changes in temperature, precipitation patterns, sea level, and extreme weather are destabilizing major determinants of human health. Children are at higher risk of climate-related health burdens than adults because of their unique behavior patterns; developing organ systems and physiology; greater exposure to air, food, and water contaminants per unit of body weight; and dependence on caregivers. Climate change harms children through numerous pathways, including air pollution, heat exposure, floods and hurricanes, food insecurity and nutrition, changing epidemiology of infections, and mental health harms. As the planet continues to warm, climate change's impacts will worsen, threatening to define the health and welfare of children at every stage of their lives. Children who already bear higher burden of disease because of living in low-wealth households and communities, lack of access to high quality education, and experiencing racism and other forms of unjust discrimination bear greater risk of suffering from climate change hazards. Climate change solutions, advanced through collaborative work of pediatricians, health systems, communities, corporations, and governments lead to immediate gains in child health and equity and build a foundation for generations of children to thrive. This technical report reviews the nature of climate change and its associated child health effects and supports the recommendations in the accompanying policy statement on climate change and children's health.

INTRODUCTION

The American Academy of Pediatrics (AAP) published its first policy statement[1] and technical report[2] titled "Global Climate Change and Children's

abstract

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Health" in 2007. These were the first reports by a US medical organization to recognize the consequences of climate change for children. These publications marked a watershed moment in medicine, whereby a leading medical society acknowledged that physicians must care for the planet to care for our patients.

The 2015 update to the technical report asserted that "A new public health movement is needed to educate, advocate, and collaborate with local and national leaders regarding the risks climate change poses to children and the major health benefits associated with mitigation policy."[3] Across the United States and the world, this movement is underway with pediatricians at the forefront. Pediatric health care professionals are educating themselves on what climate change means for children and advocating for solutions needed to safeguard the climate for children's health.

This technical report provides an overview of climate change science and describes how climate change affects health from birth through young adulthood. An accompanying policy statement[4] from the AAP provides recommendations for pediatricians and governments on climate change and children's health.

CAUSES OF CLIMATE CHANGE

Earth's climate has varied markedly throughout its history as a result of natural forces. Over the past century, however, human-generated greenhouse gas (GHG) emissions have become the predominant driver in shaping the earth's climate system.[5] The primary human-generated GHGs are carbon dioxide (CO_2), methane, nitrous oxide, and halocarbons.[6] GHGs serve as a blanket over the earth, absorbing outgoing long-wave infrared radiation reflected from Earth's surface and warming the planet (Fig 1).

Since the industrial revolution, the growth rate of CO_2 atmospheric concentration has been exponential,[6] reaching a level of 416 ppm as of July 2021.[8] Since 1750, CO_2 concentration has increased by nearly 50%, methane concentration has increased by more than 160%, and nitrous oxide concentration has increased by 23%,[9] a rate of growth unprecedented in 66 million years.[10] Between 1959 and 2019, fossil fuels accounted for 81% of total emissions and land use for 19%[11] (Fig 2). Energy supply, transportation, and industrial activity accounted for the majority of fossil fuel emissions in the United States.[12]

Current CO_2 concentration is higher than at any point in at least 3 million years, well before *Homo sapiens* evolved approximately 300 000 years ago.[13] Although both human and natural factors influence Earth's climate, the human-generated rise in GHG concentrations is the only force that can account for observed changes in Earth's climate over the past century[14,15] (Fig 3). These changes include increased global temperature, intensified precipitation cycles, raised sea levels (Fig 4), acidified oceans, reduced land and sea ice, and other changes to Earth systems.[16–18]

Future emissions will cause further warming, with each additional temperature rise resulting in more frequent and intense extremes in heat, heavy precipitation, and drought.[16] There is evidence that extreme winter cold events may be linked to arctic warming and associated changes in atmospheric circulation patterns.[15,19] Children born in 2020 will be exposed to an estimated twofold to sevenfold increase in extreme events, most notably heat waves, relative to people born in 1960, with the number of exposures increasing with greater warming (Fig 5).[20]

CLIMATE CHANGE IN THE UNITED STATES

Rising GHG concentrations are causing observed changes across a range of climatic indicators that are region dependent. In the United States, 4 primary effects are particularly relevant to child health. These include warming temperatures, intensification of the water cycle, sea level rise, and more severe storms.

Annual average temperature has increased 1.8°F (1.0°C) over the contiguous United States relative to the beginning of the 20th century, with most of that increase occurring over the past few decades. The number of high temperature records set over the past 2 decades far exceeds the number of low temperature records.[15] Globally, each of the last 4 decades has been warmer than any preceding it since 1850.[16] Attribution studies have concluded that the 2021 heat wave in the Pacific Northwest would not have occurred in the absence of human-caused climate change.[22]

Warming is not equally distributed, occurring much faster at higher latitudes. Since the middle of the 20th century, Alaska has warmed twice as quickly as the global average and faster than any other state.[23] Commensurate impacts on the environment and human health and welfare are likewise pronounced, particularly for Indigenous Alaskans who have developed deep knowledge and connection to the region over generations.[23] Because a certain amount of future warming is already "locked in" as a result of historical GHG emissions, an additional increase of 2.5°F (1.4°C) in annual average US temperature is expected regardless of future emissions. A further increase of 3°F to 12°F (1.6°–6.6°C) throughout this century is expected depending on the magnitude of future anthropogenic GHG emissions and the climate response, with greater temperature rise in higher-emission scenarios.[15]

As with temperature, changes in precipitation have not been uniform. The northern and eastern United States have experienced an increase in precipitation since 1901, whereas much of the southern and western United States have experienced a decrease.[15] Relatively more rainfall

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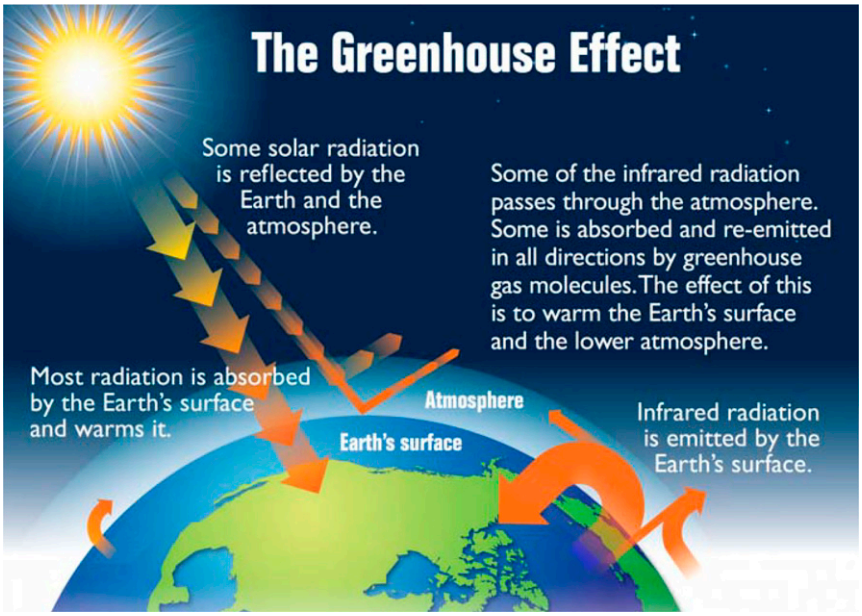

FIGURE 1

The greenhouse effect helps trap the sun's heat and is vital for maintaining a hospitable temperature for life on earth. Human activities, however, are increasing the amount of heat-trapping greenhouse gases in the atmosphere, causing the earth to warm. Source: US Environmental Protection Agency.[7]

events are manifesting as large, single-day downpours in most of the states compared with the early 20th century, with the greatest increase in the Northeast and Midwest.[15] More precipitation falling as rain rather than snow and longer, drier summers raise the risk of water shortages in arid regions dependent on snowmelt for water, such as the western and southwestern United States.[24] Less precipitation, longer warm seasons, and more heat extremes all promote wildfire risk.[25–27] Western states experienced a sixfold increase in the amount of land burned by wildfires between 1986 and 2003 compared with 1970 to 1986, associated with increased spring and summer temperature and earlier spring snowmelt.[28] Since reliable record-keeping began, 2015, 2017, and 2020 were the only years to sustain more than 10 million acres in the United States burned.[29]

Average global sea level has risen approximately 7 to 8 inches since 1900 and is accelerating. Human-induced warming of the ocean and melting of glaciers and ice sheets are very likely driving this rise, at least since 1971.[16] Regional sea level rise varies because of numerous other factors that affect sea surface height.[30] The

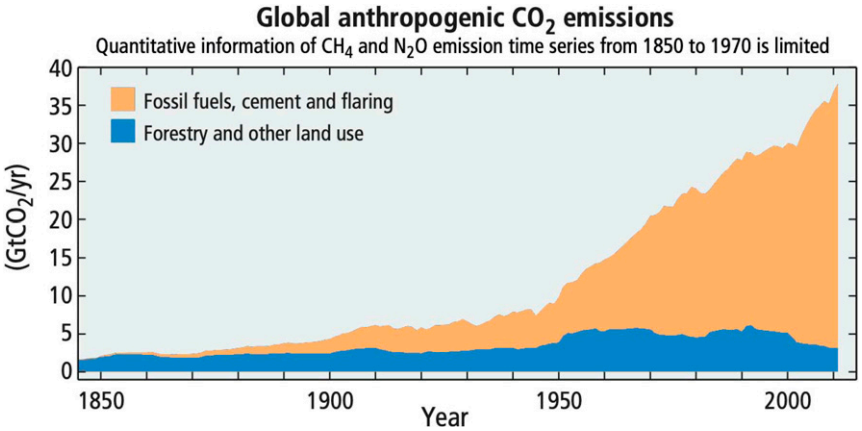

FIGURE 2

Global carbon emissions over time for fossil fuels, cement production, and gas flaring from oil and gas wells, pipelines, and other sources compared with emissions from land use change. Adapted from Friedlingstein et al.[11]

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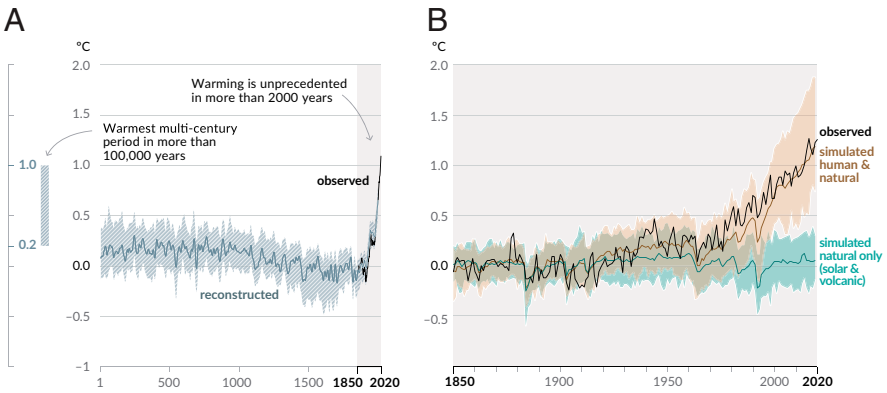

FIGURE 3

History of global temperature change and causes of recent warming. Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years. A, Change in global surface temperature (decadal average) as reconstructed (1–2000) and observed (1850–2020). B, Change in global surface temperature (annual average) as observed and simulated using human and natural and only natural factors (both 1850–2020).[16]

span of the Atlantic coastline between Cape Cod in Massachusetts and Cape Hatteras in North Carolina has the fastest rates of sea level rise in the world, 3 to 4 times the global average.[31] Climate models project an additional 1 to 8 feet of sea level rise by 2100, depending on future GHG emission rates and potential feedback mechanisms.[30] Ocean absorption of CO_2 has also increased ocean surface water acidity by 30% since the beginning of the industrial revolution.[32] This threatens fishery productivity, especially for crustaceans, and presents a major risk for important ocean ecosystems such as coral reefs.[33]

Approximately 42% of the US population lives in coastal zone counties.[34] Numerous US coastal communities have experienced deeper and more frequent coastal flooding and increased nuisance flooding associated with local relative sea level rise.[30] Heavy precipitation events have increased in intensity and frequency, particularly in the northeastern United States, and this trend is expected to continue.[35] Human activity has impacted ocean-atmospheric variability in the North Atlantic Ocean. Increases in precipitation rates and intensity of Atlantic and eastern North Pacific hurricanes and typhoons in the western North Pacific are projected. Quantifying the effect of human-induced climate change on extreme storms, however, is particularly challenging, and uncertainties remain.[36]

EFFECTS OF CLIMATE CHANGE ON CHILDREN'S HEALTH

Introduction

Observed changes in temperature, precipitation patterns, sea level, and extreme weather are destabilizing major

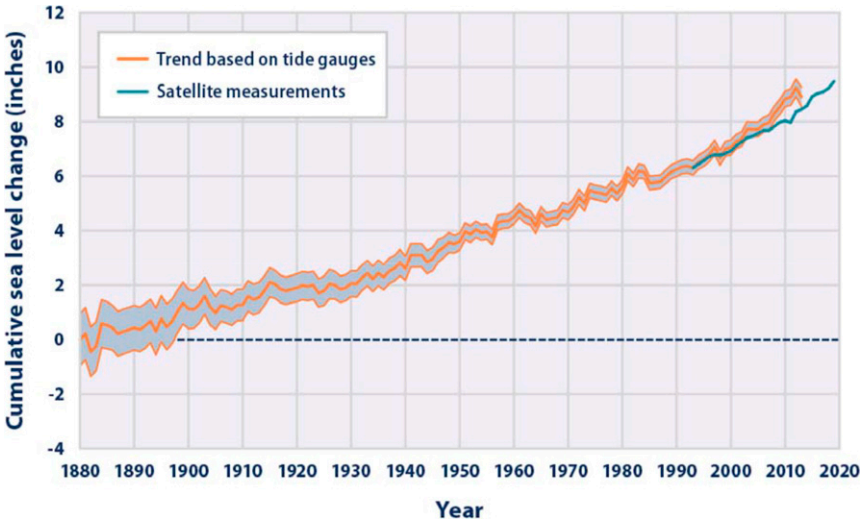

FIGURE 4

Global average absolute sea level change, 1880 to 2015.[21]

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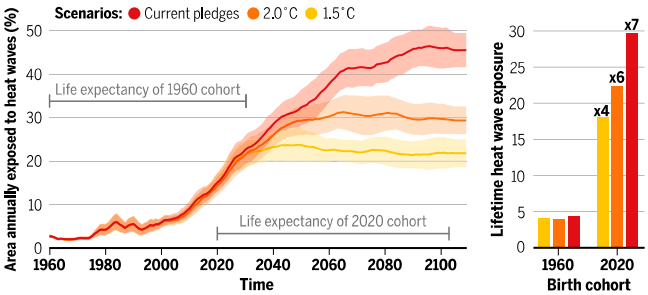

FIGURE 5

Lifetime heat wave exposure for 1960 and 2020 birth cohorts in 3 warming scenarios. Left, Global land area annually exposed to heat waves under 3 scenarios is shown. Lines represent multimodel means of a heat wave metric calculated from 4 global climate models. Lines were smoothed by using a 10-point moving average. Uncertainty bands span 1 SD across the model ensemble. Right, Lifetime heat wave exposure for the 1960 and 2020 birth cohorts under the 3 scenarios is shown. Numbers above bars indicate exposure multiplication factors relative to the 1960 cohort. Source: Thiery et al.[20]

determinants of human health. Children are at much higher risk of climate-related health burdens than adults because of their unique behavior patterns; developing organ systems and physiology; higher exposure to air, food, and water per unit of body weight; and dependence on caregivers.[37] Climate change currently affects child health through numerous pathways, including air pollution, heat exposure, floods and hurricanes, food insecurity and nutrition, changing epidemiology of infections, and mental health harms. As the planet continues to warm, climate change's impacts will worsen, threatening to define the lives of children at every stage.[38] Children who already bear higher burden of disease because of poverty, less education, racism and discrimination, or who speak languages other than English bear disproportionate risk of suffering from climate change hazards.[39,40] Despite these rising risks, increasing recognition by medical societies,[41] and calls from medical students,[42] medical school,[43] and residency education[44] has not kept pace with environmental changes.

Dramatic reductions in GHG emissions can alter this trajectory. In 2015, the United Nations Climate Change Conference in Paris reached an international treaty called The Paris Agreement.[45] The Agreement set a target of limiting global temperature rise to no more than 2°C. Meeting this target would bring not only a safer climate but cleaner air and water, more nutritious food, and healthier communities that protect the life and future of every child.

Air Quality

Ambient Air Pollution

Air pollution and climate change are intimately linked by shared causes and solutions. Children are particularly vulnerable to air pollution because of their developing lungs, small airway size, increased respiratory rates, and typically greater time spent outdoors.[46] Ambient air pollution exposure is a leading contributor to global burden of disease[47] and is associated with numerous diseases in children, including asthma, cancer, and neurodevelopmental disorders.[48] Disparities in pollution exposure are notable in part because of the inequitable location of polluting facilities.[49] Disease burden attributable to particulate matter of 2.5 μm or less in diameter ($PM_{2.5}$) has been found through satellite-derived pollution sensing and neighborhood level health data to be higher in communities of lower educational attainment and income and a higher proportion of people of color.[50]* Although $PM_{2.5}$ concentrations have decreased by approximately 70% since 1981 and gaps in exposure have narrowed, relative disparities in exposure in US census tracts have remained persistent and are associated with race, demographic factors, and poverty, regardless of urbanity or population density.[51] This section will focus on ground-level ozone, a principal component of photochemical smog.

Ground-level ozone is not emitted directly but is generated through temperature-dependent photochemical reactions between sunlight and pollutant precursor chemicals. Ozone is a potent airway irritant and well-established cause of respiratory morbidity in the warm season.[52,53] The relationship between short-term exposure to ozone and increased asthma exacerbations and hospitalizations has been well documented,[54–56] with children at greatest risk.[57] Long-term ozone exposure has been associated with impaired childhood lung function growth.[58,59] Ozone exposure during pregnancy has been associated with low birth weight, preterm birth, and stillbirth, with higher risk in Black mothers. Causal pathways were not investigated in this review.[60]

Temperature is a strong predictor of ozone levels as well as a modifier of its health impacts.[61,62] Higher temperatures resulting from climate change carry the potential to increase ozone concentrations and associated health impacts.[63] Without reductions in ozone precursor chemicals, which mainly arise from burning fossil fuels, warmer temperatures may result in as many as 9 additional dangerous ozone days each year in the Northeast, Midwest, and Southwest by the 2050s when compared with 2000 through 2009.[64]

Plant Pollen

An estimated 7.1 million US children, roughly 1 in 10, suffer from respiratory allergies.[65] Allergic rhinitis is strongly linked to asthma, with an estimated 40% of in-

*All terms referring to race and ethnicity are based on terminology in primary cited document other than capitalization, which is made consistent throughout this document.

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dividuals with allergic rhinitis having comorbid asthma.[66] Significant racial disparities exist with higher prevalence of child asthma in Black and American Indian/Alaska Native children.[67] Exposure to high levels of pollen is an important trigger for child asthma exacerbations and hospitalizations.[68]

Warmer temperature and rising carbon dioxide concentration contributes to many changes in seasonal allergies, including pollen season length, timing, annual pollen load, pollen potency, and distribution of allergenic pollen-producing species, with effects varying by allergen.[69,70]

Earlier onset of spring flowering and later first frost has been linked to increased duration of the pollen season and increased pollen load.[71–73] The onset of pollen season has advanced by approximately 20 days in parts of North America since 1990, approximately 50% of which can be attributed to human-caused warming.[74] Advancement of spring has been associated with increased asthma hospitalization in all age groups.[75] Plant pollen production is also influenced by atmospheric carbon dioxide concentration. Elevated CO_2 conditions have been shown to increase production of pollen by numerous allergenic species, including ragweed,[76,77] Timothy grass,[78] and oak.[79] Allergenicity of ragweed pollen,[80] oak,[79] and fungi[81] has also been shown to increase in elevated CO_2 environments.

Other aspects of climate change are associated with potential impacts on allergic and asthmatic disease. For example, rising sea level and increased heavy rainfall events may increase the risk of mold contamination and exposure.[66,82] Anthropogenic air pollutants also can interact with aeroallergens as adjuvants that alter immunogenicity of allergenic proteins.[83]

Wildfire Smoke

Catastrophic wildfires fueled by climate change are a rising global health concern. Exposure is expected to increase, with greater projected increase in high-emission scenarios.[84] As with ambient air pollution, children are at increased vulnerability to wildfire smoke relative to adults.[85] Exposure reduction is best achieved through relocation, use of a MERV12 or better filter with heating, ventilation, and air conditioning or fan, a portable HEPA air cleaner, and staying indoors with windows closed. Although N95 respirators offer protection, they do not fit young children, medical masks offer limited filtration, and cloth masks are not beneficial.[86] The availability of these options and ability to reduce exposure is influenced by socioeconomic factors and stands to widen existing health disparities. In a framework that encompasses landscape wildfire potential as well as socioeconomic attributes, census tracts with majority Black, Hispanic, or Native American populations have been found to have approximately 50% greater vulnerability to wildfire.[87]

Although the exact composition of wildfire smoke varies, a large portion is particulate matter, with a higher proportion of ultrafine particles than typical ambient pollution. Other components include CO_2, carbon monoxide, nitrogen oxides, polycyclic aromatic hydrocarbons, and volatile organic compounds, many of which are known to be carcinogenic.[86] It is well established that exposure to wildfire smoke causes asthma exacerbations, including in children.[88,89] In children without asthma, exposure to wildfire smoke is associated with adverse respiratory effects necessitating emergency department (ED) or urgent care visits.[90,91] $PM_{2.5}$ from wildfire smoke was found to be as much as 10 times more harmful to children's respiratory health than $PM_{2.5}$ from other sources, particularly for children younger than 5 years.[92] Exposure has been associated with adverse pregnancy outcomes, including low birth weight and preterm birth, although further research is needed.[93–95] Rates of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) positivity have also been demonstrated to increase in populations exposed to high wildfire-associated $PM_{2.5}$.[96,97]

Extreme Weather Events

Rising GHG concentrations in earth's atmosphere have fueled more extreme heat waves, precipitation events, droughts, and potentially hurricanes. Extreme heat and drought also contribute to greater wildfire risk. From 2000 to 2019, there were 6681 recorded natural hazard-related disasters, an increase from 3656 events over the previous 20 years. Although better reporting and recording can explain some of this increase, much is attributable to a significant rise in climate-related disasters. Natural disasters affect the United States more than any other nation except China.[98]

In the United States and around the world, children who live in lower-wealth homes and communities are most at risk from extreme weather events.[99] Worldwide, more than half a billion children live in extremely high flood occurrence zones, and nearly 160 million children live in areas of high drought severity.[100] When disasters strike families with the least ability to prepare or recover, children may suffer the greatest burden, as families reduce health care expenditures and withdraw children from school, perpetuating intergenerational poverty.[101] Children dependent on electronic medical technologies are particularly vulnerable to events that interrupt power supplies.[102]

Hurricanes and Floods

Climate change may be increasing the likelihood of more dangerous hurricanes. Maria (2017), Harvey (2017), and Katrina (2005) are recent examples of severe hurricanes and their consequences. The associated strong winds, heavy downpours, and storm surges can cause blunt trauma, lacerations, fractures, puncture wounds from projectile objects, drownings, and poisonings. After hurricane Irma in 2017, carbon monoxide poisoning related to power outages

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caused 16 deaths.[103] Hurricane Maria led to one of the worst humanitarian disasters in a US territory. In a survey of 96 408 public school students in Puerto Rico, 6.6% of students reported that a family member, friend, or neighbor died during the hurricane, and 30% believed their own life was at risk. Of interviewed children, 4% reported being injured; 16% reported injury in a friend, family, or neighbor; and 24% reported rescuing others.[104]

Deaths among children during hurricanes and in their immediate aftermath are fortunately relatively infrequent. After hurricane Harvey, children younger than 18 years accounted for 9% of the storm's total 70 fatalities.[105] Children in lower-resource communities and nations, however, have higher risk of injury and death after weather disasters.[106]

Hurricanes, which destroy homes, communities, workplaces, and property, present risks to child health and welfare. Hurricane Harvey was second only to hurricane Katrina in US history in terms of economic losses.[107] These losses impose the greatest financial strain on the lowest-wealth households, and may jeopardize health care access, food security, and housing stability for vulnerable children.

Hurricanes can lead to greater demand for health care. ED visits by evacuees of Harvey substantially increased outside the storm-impact zone. In Dallas-Fort Worth, 10 hospitals experienced ED surges of 600%, and 2 hospitals had surges greater than 1000%. Approximately 25% of visits were for gastrointestinal complaints, with a significant increase in visits for nausea, vomiting, and diarrhea. More than a quarter of these patients were children younger than 18 years.[108]

Floods from heavy precipitation are the most common weather disasters globally.[98] Although extreme precipitation contributes to flooding, the impact of human-induced warming on inland flooding is difficult to discern because of compounding variables.[15] A primary difference between flooding from hurricanes and other storms are the populations at risk. Gulf and Atlantic coastal populations are most at risk from hurricanes, whereas heavy downpours from storms affect the interior of the United States.

Floods are associated with mold exposures and outbreaks of waterborne diseases.[109–112] Pathogen contamination of water can cause skin, soft tissue,[113] and gastrointestinal tract infection.[114] Hurricane Harvey delivered the highest total rainfall in US history, when 19 trillion tons of water, equivalent to 1 year of rainfall, fell in just a few days in the Houston area. This overwhelmed wastewater facilities for an extended period, leading to unprecedented sewer overflows.[115] Sixty-one public water systems and 40 wastewater treatment facilities were destroyed or became inoperable, requiring boil-water notices in more than 200 public water systems. A total of 266 hazardous material spills or discharges were reported or observed,[116] and 8 million cubic yards of trash as well as a toxic mix of chemicals, sewage, and biohazards contaminated floodwaters in the Dallas-Fort Worth area.[108]

When water purification systems fail, communities are often given orders to boil water or use bottled water; compliance may be difficult in low-wealth households.[114,117] Communities that combine storm water and sewage in the same pipes are at increased risk for water contamination.[118]

Wildfires

Like hurricanes and floods, wildfires may cause immediate injury or death, primarily in adults.[119] They can destroy homes, property, and neighborhoods, which can destabilize child health and welfare. Wildfires have also been studied for their mental health effects, and children and adolescents, in particular, are at risk for anxiety and post-traumatic stress disorder (PTSD) symptoms after wildfires.[120] Wildfire smoke is a cause of significant respiratory compromise in children, as described in the air quality section of this document. Socioeconomic factors, which influence capacity to prepare, respond, and recover, strongly influence vulnerability to wildfires.[87] Historical forced concentration onto reservation land with higher wildfire hazard, particularly in the Western United States, has placed Native Americans on these reservations at particularly elevated risk.[87]

Undermined Foundations of Child Health

Extreme weather undermines foundations of healthy child development, including stable families, schools, neighborhoods, and communities. After devastation from extreme weather, children experience harm to their health, safety, education, and development, with impacts that can be lifelong.[121]

Perinatal Health

Exposure to weather disasters, including hurricanes and flooding, may be associated with adverse maternal and neonatal outcomes, including preterm birth, low birth weight, and spontaneous miscarriage, although data are limited and inconsistent.[122–126]

Population Displacement

Extreme weather events of any form may promote housing instability for children and increase the odds of forced displacement.[106] After hurricane Harvey, for example, almost 780 000 people were evacuated,[107] and a single shelter housed approximately 10 000 displaced people.[127] Hurricane Michael in 2018 was one of the most destructive storms in US history. A Category 5 storm with devastating storm surge and winds, it caused $25 billion in damage and led to 16 direct and 43 indirect deaths.[128] Storm-related damage and displacement kept 4000 children in the Florida Panhandle out of school 8 months later, and many families remained displaced and without a permanent address.[129] In response, Florida created a special coordinator's office focused on addressing mental health needs in the wake of

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hurricanes and other disasters.[130] Displaced children are at risk for infectious disease outbreaks in crowded shelter conditions,[131] reduced access to health care services including vaccinations,[132] and increased risk of violence, particularly in families experiencing food and shelter insecurity.[133]

Many child health risks associated with extreme weather are discussed in greater detail elsewhere in this document. These include disruption in health care delivery (clinical care), mental health harm (psychosocial), and disproportionate vulnerabilities (environmental justice).

Extreme Heat

Greater exposure to extreme heat is one of the clearest consequences of climate change. Heat exposure broadly affects child health. Children and adolescents may have equal ability to thermoregulate their bodies as adults except in extreme conditions but take longer to acclimatize to higher temperature and/or humidity.[134] Infants and young children are also developmentally unable to enact behavioral modifications in response to heat.[135]

A subset of heat-health impacts is labeled specifically as heat-related illness (HRI). HRI includes a continuum of illness ranging from mild (heat edema, cramps, syncope, and stress) to moderate (heat exhaustion) to severe and potentially fatal illness (heat stroke), which is classified as nonexertional (classic) and exertional.[135] Heat exposure has also been associated with pediatric renal disease and electrolyte disturbances,[136] all-cause ED visits,[137,138] infant mortality, adverse pregnancy outcomes, and negative effects on cognition and academic performance. Observational studies indicate that the incidence of HRI is increasing as the planet warms, with children composing almost 50% of those affected.[135]

Exertional heat illness (EHI) is a significant health concern in high school athletes. Football players have a higher risk than all other athletes,[139] and preseason football practice is the highest risk period, with 1 study finding 83% of EHI football events occurring during preseason practice.[140] This increased risk at the start of the season is related to high ambient temperature at that time of year, lower physical conditioning, lack of heat acclimatization of players, and multiple daily practices.[141] Fatal and life-threatening heat stroke was found to be 10 times more common than severe cardiac events in long-distance races in Israel.[142]

Heat stroke remains a significant cause of death in high school and college football that has continued to rise.[141,143] It has been observed that EHI, including fatal injury, occurs at lower wet bulb globe temperatures (which account for temperature, humidity, wind speed, sun angle, and cloud cover) in cooler, higher-latitude climates.[144,145] Players on medications that decrease sweating or increase heat production (stimulants, antihistamines, psychiatric medications); those with medical conditions such as obesity, diabetes, or sickle cell disease or trait; and those who are less conditioned have increased risk.[135]

EHI in young athletes is preventable. The National Athletic Trainers' Association Interassociation Task Force released guidelines for preseason heat "acclimatization" in 2009,[146] promoting gradual acclimatization during the first 2 weeks of the preseason. One study found that mandating these guidelines by the state high school athletic association was associated with a 55% reduction in the incidence of EHI.[147]

Young military recruits are another at-risk population. A study of HRI in active service members found that the annual rates of heat stroke and exertional rhabdomyolysis increased steadily between 2014 and 2018, with more than 92% of these illnesses occurring in the United States.[148,149] Recruits younger than 20 years during the first few months of military service are at highest risk.[148,150] Higher rates of illness have been noted in higher-latitude locations, suggesting lower levels of acclimatization. Use of tobacco, nonsteroidal anti-inflammatory drugs, opioids, and stimulants has been found to be a risk factor for HRI.[150]

Child agricultural workers are also at high risk for HRI. Between 2005 and 2016, there were an estimated 30 000 to 79 325 child farmworkers aged 10 to 17 years hired in the United States. The majority of these children are of Latinx origin. A study of Latinx child farmworkers in North Carolina found that 45.5% had experienced an HRI while working over the previous 12 months.[151] Chronic heat stress and recurrent dehydration may contribute to chronic kidney disease of unknown etiology and kidney failure.[152,153]

Infants and adults older than 65 years have been consistently shown to be at highest risk of heat-related mortality.[136,154–156] Declines in heat-related mortality in the United States since 1960 can be explained almost entirely by air conditioner use, with greatest protective effect in infants and the elderly.[157] Access to potentially life-saving air conditioning highlights the socioeconomic factors that influence climate vulnerability.[158] Infants and young children are at particular risk of hyperthermia after entrapment in a motor vehicle. An average of 38 children die each year from this cause, with 42 child deaths in 2017. These events are most commonly attributable to parental distraction or fatigue or to children becoming entrapped after gaining access to a vehicle. Numerous educational programs have been developed and state laws enacted to prevent these tragic accidents.[159]

Maternal heat exposure has been associated with adverse birth outcomes,[160] including preterm birth,[161–165] low birth weight,[166–169] and infant mortality.[170,171] Higher rates of adverse birth outcomes associated with heat have been observed in Black mothers, although causal pathways have not been identified.[60] Although further research is needed to include individual temperature exposure and vulnerable exposure windows,[172] current research suggests

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pregnant women have an elevated risk of adverse health effects from heat exposure and should be targeted in public health warnings.[173]

Beyond physical harms, heat may impair learning. Exposure to higher temperature has been associated with reduced cognitive function[174,175] and educational achievement.[176] A study of 10 million PSAT-takers found that, in schools without air conditioning, each 1°F increase in average school year temperature reduced the amount students learned that year by 1%.[177]

The adverse effects of heat on children's health are compounded for children living in cities by the additional contributor of the "urban heat island effect."[178] Cities tend to have less greenspace and more synthetic dark surfaces that absorb heat. Varying degrees of tree cover and building density can cause temperatures to vary within a single urban region by as much as 10°C,[179] a discrepancy that has been linked to historically racist housing policies.[180] Heat is also generated by vehicles and building energy waste, with air conditioning use intensifying heat emissions in a positive feedback spiral.[181]

Infectious Diseases

Climate change influences temperature, precipitation, and warm-season duration, all of which can influence the spread of vectorborne disease.[182] Lyme disease is the most common vectorborne disease in the United States.[183] Between 2001 and 2019, male children 5 to 14 years of age had the highest incidence of Lyme disease in the United States.[184] Between 2004 and 2016, the number of annual reports of tickborne bacterial and protozoan diseases in the United States more than doubled, with Lyme disease accounting for 82% of all tickborne disease reports.[185] The number of counties in northeastern states with a high incidence of Lyme disease increased more than 320% between 1993 and 2012, and counties in north-central states with high incidence increased approximately 250%.[186]

Changes in land use, host animal abundance, habitat fragmentation, and warming temperatures have been identified as contributing factors in *Ixodes scapularis* range expansion as well as the longer season for Lyme disease transmission.[187–190]

Other tick vectors of human disease are also expanding their range. The lone star tick, *Amblyomma americanum*, is the tick most frequently reported attached to humans in the Southeast and Atlantic states.[191] It can transmit *Ehrlichia* species, *Francisella tularensis*,[192] and *Rickettsia* species.[193] The lone star tick has also been associated with galactose-α-1.3-galactose allergy and Southern tick-associated rash illness. Range expansion northward and westward over the last several decades is attributed to similar drivers as for *I scapularis*, and the lone star tick is anticipated to spread into Canada with rising temperatures.[192] Expansion of the lone star tick range has been associated with significant increase in reported cases of mild cases of spotted fever group rickettsiosis.[193]

Warming temperatures and changing precipitation patterns attributable to climate change also affect mosquitoes and the pathogens they may carry. Although temperature increase may enable the survival of mosquitoes in currently uninhabitable locations, it also has been projected to make currently suitable locations too hot for mosquito survival.[194,195] Range reduction, extinction of some vector species, and reduced disease transmission is possible as global temperatures rise.[196,197] Projecting how climate change influences mosquitoborne disease epidemiology also must incorporate disease eradication efforts that have, for instance, dramatically reduced malaria incidence in much of Africa in recent decades.

Aedes aegypti and *Aedes albopictus* mosquitoes are the vectors of numerous diseases including dengue, Zika, and chikungunya. These mosquitoes have rapidly expanded their range in the past decade and currently inhabit the widest global distribution ever recorded.[198,199] In 2019, the region of the Americas reported 2 733 635 cases of dengue, the largest number ever recorded in the region, exceeding the number reported in the epidemic year of 2015 by 13%. Climate change may be one factor contributing to greater spread of these diseases, in addition to rapid unplanned urbanization, increased trade and travel, and land use changes.[200] Climate models suggest that one billion people will become newly at risk from *Ae aegypti* and *Ae albopictus* within this century in intermediate climate change scenarios. The greatest increases are expected in North America, among other regions.[194] Under a medium climatic scenario, *Ae aegypti* is predicted to spread in the United States as far north as Chicago by 2050. *Ae albopictus* is projected to become more broadly established in northern latitudes of the country, and some locations in the central southern United States are predicted to become less suitable because of increased aridity.[201] The transmission potential of *Ae albopictus* may decrease in some regions as temperatures exceed the upper thermal limit for transmission.[194]

The impact of climate change on infectious disease in children is not limited to those diseases carried by vectors. Hand, foot, and mouth disease (HFMD), a common human enterovirus infection, is generally mild and self-limited in the United States, where it tends to have a single seasonal peak. However, in Asia over the past few decades, HFMD has caused large-scale outbreaks of more severe disease. A literature review identified a positive, statistically significant relationship between HFMD cases and both temperature and relative humidity. No significant relationship was identified between HFMD and wind speed, sunshine, and/or precipitation.[202]

Coccidioidomycosis, or "valley fever," is caused by inhalation of dust containing *Coccidioides* fungal spores. Infection generally occurs in hot, dry regions of the southwestern United States, although 16 cases originating in Washington

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State have been reported since 2010.[203] Most exposed people are asymptomatic, but some develop fever, lung disease, nervous system involvement, and rarely death. Adults are at highest risk, but children are also affected. Valley fever is one of the most commonly reported infectious diseases in Arizona, where cases have increased dramatically since it first became a reportable disease in 1997, peaking in 2011.[204] In 2018, 216 children younger than 15 years were affected in Arizona.[205] A record 9012 cases of valley fever were reported in California in 2019, a 288% increase from 2014 (2322 cases). Although reasons are not fully understood,[206] climate and environmental factors may be contributing to this rise.[207,208]

Diarrhea is a major global child health concern, causing more than 500 000 deaths in children younger than 5 years in 2015.[209] Changes in ambient temperature, precipitation patterns, and extreme weather events alter diarrheal diseases through impacts on individual pathogens, water sanitation systems, food safety protocols, and via greater food insecurity and malnutrition (see Food Security and Nutrition, below).[210]

Recent systematic reviews have found bacterial diarrheal illness may be more likely with higher temperatures, heavy rainfall, and flooding events.[210,211] Increased incidence of *Escherichia coli*,[212] *Salmonella*,[213,214] and *Campylobacter*[215] infections has been associated with elevated ambient temperature. Zinc deficiency underlies large shares of childhood morbidity and mortality from diarrheal diseases as well as malaria and pneumonia.[216] Zinc content of staple foods, including wheat, rice, barley, and field peas decreases when crops are grown in higher concentrations of atmospheric CO_2, putting more children at risk for zinc deficiency and worse outcomes from diarrheal and other infections.[217]

Noncholera *Vibrio* species, including *Vibrio parahaemolyticus* and *Vibrio vulnificus*, grow in warm, low-salinity waters, and their abundance is largely determined by temperature.[218] They cause gastrointestinal disease when contaminated seawater or undercooked contaminated seafood are ingested as well as wound infections with risk of sepsis.[219] *V vulnificus* has the highest mortality rate of any foodborne pathogen and is responsible for more than 95% of deaths attributable to seafood ingestion.[220] *Vibrio* infections have been appearing in higher latitudes, often during heat waves.[218,221] This increase has been associated with an increased abundance of *Vibrio* species in the North Atlantic and North Sea associated with increasing sea surface temperature.[222]

In summary, climate change is influencing infectious disease dynamics and child health. These changes occur in the wider context of complex social, economic, and biological phenomena that make isolation of climate influence challenging. Although uncertainties persist, clinical vigilance for emerging infections and research to prioritize strategies for disease prevention are warranted,[223] with special consideration of children's unique needs and vulnerabilities.

Food Security and Nutrition

Global food production has increased dramatically in the past 60 years as a result of synthetic fertilizers, mechanization of agriculture, and development of higher-yielding grain varieties. Despite this enormous public health success, global malnutrition remains a profound child health concern.[224] The projected need to produce 50% more food[225] to feed an expected world population of almost 10 billion by 2050[226] raises major concerns for the future of child nutrition. Malnutrition, encompassing the "triple burden" of undernourishment, overweight and obesity, and micronutrient deficiencies,[227] includes leading risk factors for disability adjusted life-years in children 0 to 9 years of age.[228,229]

The number of people who suffer from hunger has steadily increased since 2015, reversing decades of progress. This increase has occurred across Africa, Western Asia, and to a lesser extent, Latin America.[230] The coronavirus disease 2019 (COVID-19) pandemic led to widespread increased food insecurity associated with higher food prices in 2021, and impacts are expected to continue into 2022 and possibly beyond.[231] Undernutrition is linked to an estimated 45% of deaths in children younger than 5 years.[232] Malnutrition is also a cause and consequence of diarrheal disease, another leading cause of child morbidity and mortality in developing countries.[233,234] In the United States, as many as 1 in 7 children may not know the source of their next meal.[235] Significant racial disparities exist, with an analysis of 2018 US food insecurity finding rates at least twice as high in Black, non-Hispanic, and Hispanic as in white, non-Hispanic households.[236]

Climate change effects, including higher temperatures, weather extremes, altered precipitation patterns, altered pest and pathogens, declines in fisheries, disruptions in insect pollinator services, and economic downturns and conflict contribute to these trends in child malnutrition.[224,225,230] In the United States, climate change-associated extreme weather, including heat waves and floods, have resulted in major crop and livestock losses. For example, the historic 2019 floods in the central United States destroyed millions of acres of agricultural land, killed thousands of livestock, and caused widespread damage to infrastructure, preventing access to food, particularly for those already at risk.[99]

At the same time, as children around the world are at risk for hunger, overweight and obesity affects more than 40 million children globally, an increase of 1 million since 2000.[237] Increasing calorie availability in emerging countries has been associated with a "nutrient transition" away from cereal staples and toward greater intake of resource-demanding, GHG-intensive foods of animal origin, which are a significant contributor to noncommunicable

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diseases such as heart disease, diabetes, and cancer.[227,238,239] More than 1 in 3 children in the United States is overweight or obese.[240]

Children are also commonly affected by micronutrient deficiencies. Iron is the most common micronutrient deficiency in humans,[241] and children younger than 5 years globally have the highest prevalence, severity, and long-term effects of anemia.[242] Approximately 7% of US children 1 to 5 years of age are deficient in iron, placing them at risk for anemia and impaired neurocognitive development.[243] Zinc deficiency, which affects about one-third of the global population, is associated with increased risk of preterm birth, poor growth in infants and children, and worse outcomes from infections.[244] More than half of female adolescents 10 to 20 years of age in low- and middle-income countries are not consuming adequate amounts of micronutrients, including iron and zinc.[232]

These micronutrient deficiencies may become more common as atmospheric CO_2 concentrations rise. Higher atmospheric CO_2 can reduce protein, zinc, and iron in staple crops such as wheat, rice, and vegetables.[244–249] CO_2 concentrations are on track to exceed 550 ppm by 2100. This may result in an additional 175 million people deficient in zinc and 122 million deficient in protein; 1.4 billion children will live in regions at highest risk of iron deficiency.[250] Reducing CO_2 emissions to meet Paris Agreement targets may avert 48% of the disease burden attributable to these deficiencies.[251]

Roughly 3 billion people worldwide rely on seafood as a primary protein source.[252] Fish are also a crucial source of micronutrients, such as iron, zinc, omega-3 fatty acids, and vitamin A. Seafood offers children a favorable nutritional, and in some cases, sustainability profile compared with other sources of animal protein.[253]

Global fish catch peaked around 1996 and has since declined by approximately 1% (1.22 million tons) yearly.[254] If current declines in fish catch continue, it is estimated that 11% of the world's population will be at risk for deficiency in iron, zinc, and Vitamin A.[255] Adaptive management using an ecosystem approach will be vital to ensuring resilience of sustainability of fisheries and the dependent communities.[256]

GHG emissions threaten fisheries as a result of ocean warming and acidification, sea level rise, changes in precipitation, and evaporation. These impacts have already had unequivocal impacts on marine fisheries in some regions and pose risks to all regions in the future.[256]

Climate change affects food safety and access along the entire food supply chain. Climate change may contribute to foodborne pathogen growth, survival, persistence, and dispersal through warming; changes in precipitation patterns and extreme weather; and disrupting infrastructure (eg, water filtration facilities).[257–259] Climate change-associated storms and power outages disrupt refrigeration as well as food distribution systems, threatening both the safety and sufficiency of the food supply.[260] These outcomes are of particular concern given the rising incidence of foodborne illnesses in the United States.[261]

The global food system also contributes up to 30% of global GHG emissions.[262] Rising food demand from a growing population and greater demand for meat in the diet are likely to increase emissions by about 30% to 40% by 2050.[225] A shift to more plant-based diets with less saturated fat, refined grains, added sugars, and highly processed foods would have tremendous public health and economic benefits,[263] averting an estimated 10.8 to 11.6 million (19% to 23.6%) deaths yearly worldwide.[262] Diets that require fewer GHG emissions can be achieved while preserving cultural acceptability, affordability, and nutritional adequacy, particularly in high- and middle-income countries.[239,263–265] Policies aimed at reducing emissions, however, must be carefully designed to avoid greater food insecurity in vulnerable populations as conversion of crops into fuel and afforestation could reduce food production, increasing food prices.[266–269]

Psychosocial Effects

Climate change is emerging as a major influence on child mental health and well-being.[270] Exposure to disasters, including hurricanes, floods, and wildfires, cause mental trauma and can be defining moments in the lives of affected children through loss of life and family members and devastation of the communities.[271,272] Compared with adults, children may demonstrate more severe distress after natural disasters.[271,273,274] Children exposed to natural disasters experience symptoms of PTSD,[274–277] depression, and anxiety. Alternatively, exposed children may present with aggression and conduct disorder, exhibit suicidal thoughts, or engage in substance abuse.[104,278,279] High temperature exposure has also been linked to suicide risk, violent behavior, and crime.[280–283] Disasters also interrupt education[284] and have been associated with reduced academic performance.[285]

CHILDREN AFFECTED BY HURRICANE MARIA

With an estimated $90 billion in damages, hurricane Maria in 2017 was the third costliest hurricane in US history after Katrina in 2005 and Harvey in 2017.[286] After the hurricane, a study of 96 108 public school students in Puerto Rico grades 3 through 12 found high levels of disaster-related stressors. More than 4 of 5 of the students saw houses damaged, more than half had a friend or family member leave the island, nearly 1 in 3 experienced a shortage of food or water or perceived their lives to be at risk, and 1 in 6 had no electricity 5 to 9 months after the hurricane. In total, 1 in 14 surveyed students reported clinically significant symptoms of PTSD.[104]

More exposure to (ie, directly witnessing a home destroyed by a fire as compared with hearing about it from

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another person) and personal loss from extreme weather events has been associated with more adverse mental health outcomes, but social support can be protective.[287]

The mental health burden of disasters on caregivers also falls on children.[288] High levels of maternal stress related to weather disasters during the prenatal and early-postnatal period may increase risks of psychopathology in children of affected mothers.[289–291] Children may also be at greater risk for abuse after natural disasters, with food, water, and shelter insecurity elevating risks.[133]

Support for caregivers during and after disasters, such as ensuring basic necessities and reliable information, can increase resilience among their children.[292] In New York City, for example, a community-based program focused on mental health and resiliency after Hurricane Sandy. Workshops sought to decrease mental health stigma and develop coping skills. A mobile mental health clinic was deployed to improve outreach. These interventions and others demonstrated benefits to mental health around disasters.[293]

Mental health also suffers with climate change-forced migration. Climate change-influenced weather extremes can lead to loss of basic resources, including food, water, and shelter, and economic hardship, forcing people to relocate. For families with limited means and those affected by decades of structural racism, such losses can create a widening spiral of disparity. More chronic environmental stressors associated with climate change, such as sea level rise and drought, can result in planned migration when adaptation is not possible. This is of particular concern for Indigenous peoples across the United States, many of whom are facing relocation in response to climate-related ecological shifts or disasters.[294] More than 87% of Alaska Native communities are affected by flooding and erosion. Reductions in sea ice, increased storm intensity, relative sea level rise, and thawing permafrost threaten resources and habitable terrain, potentially forcing community relocation.[23] Distressed migration undermines the social structures and interpersonal attachments that underlie healthy child development.[106]

Adults displaced to shelters after hurricane Sandy in 2012 and hurricane Harvey in 2017 were more likely to experience depression, anxiety, and PTSD.[127] As mentioned previously, children of these adults may bear a mental health burden as a result. Exposure to climate-associated disasters and potential distressed migration also represent significant trauma that can contribute, in the absence of supportive caregivers, to toxic stress. This toxic stress can result in a range of negative psychosocial and health outcomes that can extend into adulthood.[295,296]

Beyond the immediate psychological stress of climate change-influenced disasters, the long-term and potentially catastrophic outcomes associated with unmitigated climate change present a rising mental health concern in children. The majority of American children are receiving education about climate change and are exposed to media reporting on its harmful effects. Yet, they have little agency to affect change.[297] This lack of control can promote anxiety, sadness, hopelessness, and anger.[273] Ecoanxiety—manifesting as panic attacks, insomnia, and obsessive thinking related to climate change[298]—has been well-described.

A growing youth climate movement is enabling children to influence decision-making, shape their future, and promote psychological well-being.[299] Inspired by the youth climate movement, the United Nations Secretary General launched the Youth Advisory Group on Climate Change in July 2020 as a means to amplify the voices of and engage young people in the United Nations climate strategy.[300]

Clinical Care

Climate change harms child health through disruptions in health care delivery. Extreme weather events of increased frequency and/or severity attributable to climate change place health care access, infrastructure, and supply chains at risk. Designing health systems for climate resilience and disaster preparedness is, thus, vital preventive care.[301] Recent disasters offer cases in point.

After hurricane Harvey, 20 hospitals were closed or evacuated. Texas Health and Human Services participated in 3200 medical patient evacuations and 990 medical response missions.[302] Hurricanes Irma and Maria caused widespread damage to the infrastructure and electrical grid in Puerto Rico,[303] resulting in cold-chain failures that disrupted vaccine storage and immunization programs. More than 18 months elapsed before vaccine clinics could be restored.[304]

After hurricane Laura made landfall in Lake Charles, Louisiana, on August 27, 2020, 19 infants in the NICU were evacuated, first from Lake Charles Memorial Hospital because of the risk of storm surge, and a second time from the regional health system's main campus because of water and power outages in the weeks after the storm. The infants were transferred to hospitals across the state.[305]

Hurricane Sandy similarly caused hospital evacuations in New York City because of losses of power and water, including New York University Bellevue and Langone Hospitals. At Langone Medical Center, infants in the NICU were emergently evacuated down from the ninth floor via an unlit stairwell, as the elevators were inoperable.[306–308]

The November 2018 Camp Fire, the deadliest wildfire in the history of California, burned parts of the Adventist Health Feather River Hospital to the ground and forced the evacuation of 60 patients to hospitals between 15 and 30 miles away, often in personal vehicles of hospital employees.[309,310] In some instances, traffic jams forced

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ambulances to abort transfer and arrange for patient airlifts to other hospitals.[309]

Hurricane Maria provides a prominent example of how climate change may contribute to critical supply chain shortages. Puerto Rico is a major site of pharmaceutical and medical manufacturing and supplies, which represents at least 33% of the island's gross domestic product. It is the home of 50 drug manufacturing and 40 medical device manufacturing firms and supplies 8% of medicines[311] and 44% of intravenous fluid bags[312] used by Americans. The devastation brought when Maria made landfall on Puerto Rico on September 20, 2017 created a major challenge in medical product availability for Americans. The US Food and Drug Administration created a new task force and dedicated hundreds of staff in response.[311] The storm incapacitated the primary manufacturing facility for small-volume intravenous fluid bags commonly used to deliver medications, causing a national shortage.[313,314] This cascaded into changes in medications used and mechanisms of medication administration that were associated with adverse events for patients.[315]

Climate change has less obvious effects on health care as well, particularly in pediatric practices. Power outages have become more frequent over the past 20 years in the United States. These outages are primarily from extreme weather, especially severe storms, floods, and heat waves.[316] Pediatric clinics are often in buildings without backup power supplies. This lack of backup power puts medications and vaccinations at risk for spoilage. For vaccines, the Centers for Disease Control and Prevention recommends that practices maintain a backup storage site, but if the power failure resulted from extreme weather, accessing the backup site may be difficult. In light of possible greater risks of extreme weather to power supplies, pediatric practices must consider new contingency plans, especially for vaccines that require refrigeration and that disasters may demand, such as tetanus vaccine. Power outages also put at risk the welfare of patients who depend on electrically powered medical devices, and care providers should work with families on contingency plans.

Aside from disaster preparedness, pediatric care providers must consider the implications of climate risks directly to clinical practice. For instance, research in adults has shown that many commonly prescribed medications, including antihypertensives, selective serotonin reuptake inhibitors, and nonsteroidal anti-inflammatory drugs, impact thermoregulation and may increase risk of HRI or death,[317] although data are limited in children. Providing anticipatory guidance may be warranted about risks to children and families about medications, such as antipsychotics, anticholinergics, or diuretics, that are known to impair water and temperature homeostasis. This is especially important when these medications are initiated or uptitrated in the spring or early summer, as risks of HRI tend to be highest during the first heatwave of the season.[318]

Given these and other issues, the idea of climate-informed pediatric care has emerged to describe child health care provision that reflects climate-related risks.[319] Pediatricians need to be aware of shifting risks in their region of practice as the climate changes. Heat risks, for example, may be most pronounced in the Eastern half of the United States (Northeast and Midwest), as these regions either have been more temperate and inhabitants less well adapted to heat exposure (eg, the Midwest), or heat exposures grow so extreme as to make current adaptation measures inadequate (eg, the South).[282] Hurricane risks, although well known to Gulf coast states and the southern Atlantic coast states, may be shifting, as the latest science suggests that hurricane tracks may be moving northward.[320] Lastly, wildfire risks have grown already in many parts of the West, but new risks from fires and smoke are anticipated in the upper Midwest.[321]

Environmental Justice

The effects of climate change often act as a threat multiplier for those already disadvantaged. Children and families who are poor, are nonwhite, have less education, and speak languages other than English are often at increased risk of suffering from the hazards of climate change described above.[39,40] Climate change effects can magnify health disparities resulting from racism and discrimination.[322] Furthermore, these vulnerable populations are often excluded from decisions surrounding the adaptation and mitigation policies necessary to address climate change.[40,323–325]

Extreme heat resulting from climate change disproportionately affects people of color and those of lower economic status residing in urban areas because of the built environment and historical discriminatory policies.[180,326] Children in these communities may have reduced access to air conditioners or public cooling centers.[158,327,328] In a study of extreme heat event vulnerability in New York City, deaths during heat waves were more likely to occur in Black non-Hispanic residents and those who received public assistance.[329] Similarly, a study in King County, Washington, revealed a disproportionate increase in heat-related emergency medical service call volumes for those living in poverty compared with those who are not on high-heat days.[330]

The hottest urban areas are often those inhabited by communities of color, residents of limited resources, and people affected by historically racist housing policies. The inequity of heat distribution within urban areas has been linked to the historical discriminatory practice of redlining, a consequence of the Home Owner's Loan Corporation promulgation of "Residential Security" maps to distinguish neighborhoods based largely on racial makeup. Although banned officially in the 1968 Fair Housing Act, formerly "hazardous" neighborhoods remain largely populated by

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people of color and low- or moderate-income residents. In one study, former "hazardous" neighborhoods in 94% of urban areas were found to be as much as 7.4°C hotter than former "best" neighborhoods.[180] This and other studies highlight the increased vulnerability of children in low-resource communities to extreme heat and the benefits of increased tree canopy in reducing risk.[327]

Outside of urban areas, children of historically marginalized groups may face outsized risks from climate change. Children of Latinx farmworkers are not only dependents but workers themselves. In a study of occupational injuries in Latinx child farmworkers 10 to 17 years of age, 45.5% reported heat-related illness while working over the past 12 months.[151]

Some communities of color as well as low-income families are also exposed to more air pollution that is a causative agent of numerous noncommunicable diseases in children, including asthma, cancer, birth defects, and neurodevelopmental disorders.[331] Fossil fuel combustion emits most of the world's GHG emissions as well as air pollutants, such as particulate matter, that have immediate adverse health effects. In a national study, Black, impoverished, and nonwhite people are 1.54, 1.35, and 1.28 times, respectively, more likely to be exposed to $PM_{2.5}$.[49] Tracts that were affected by the historically racist housing policy of redlining have a 13.9 times increased incidence of ED visits for asthma.[332] Tessum et al demonstrated that $PM_{2.5}$ pollution is disproportionately caused by non-Hispanic white communities, but the toxic effects are borne most heavily by Black and Hispanic communities.[333] Similarly, a 2017 study showed that Chinese and Korean Americans are more likely to reside in areas with increased burdens of carcinogenic hazardous air pollution, particularly if they are not English speaking.[334] This pattern of inequitable distribution has remained consistent over time,[51] and recent mitigation efforts have even widened the chasm of differential exposure.[335,336]

Populations vulnerable to climate risks are often least able to adapt or respond to them.[40] A 2018 study found Black, Hispanic, and Native American communities are approximately 50% more vulnerable to wildfires because of reduced resources for preparation and recovery.[87] Similarly, when large storms and flooding from major hurricanes occur, Black and Hispanic populations are likely to spend more days evacuated, without power or heat, and suffer longer disruptions to their health care.[109,337,338] International climate injustice is a profound concern, with low-income countries contributing least to global emissions often suffering the greatest consequences.[339,340]

The disproportionate impact of climate change on the health of the American Indian population warrants special consideration. This population is often faced with increased exposure to the effects of climate change, and several factors have increased vulnerability. A review of environmental justice literature found a targeting of Native American lands for unwanted uses such as resource extraction, dump sites, and weapons-testing facilities.[341] Centuries of trauma, displacement, and discrimination have led to increased underlying health comorbidities.[40] The threat is also existential. Climate change is destroying "first foods" that are essential to traditional nutritious diets as well as Native American spiritual health.[341]

The burdens of climate change are distributed unfairly not only socially and geographically, but also generationally. The detrimental effects of today's fossil fuel extraction and combustion reach centuries into the future, jeopardizing the health, safety, and prosperity of today's children and future generations. Young people today increasingly recognize themselves as victims of poor governmental policies, the consequences of which will be borne by them and their children. The failure of governments to prevent rising global temperature represents a denial of children's fundamental right to a safe and sustainable future and is the foundation for the rising youth climate movement.[342]

SUMMARY

Pediatricians today are caring for children at a pivotal time in history. As medical and technological advances excel at protecting children, accelerating climate change has emerged as a threat to the children we serve. Climate change matters to the physical and mental health of all children, and especially to those who are disadvantaged. Although these findings raise our concern, the work of pediatricians and young people raise our hopes.[343] Since this report was last published in 2015, pediatricians and their young patients have emerged as leaders for the climate solutions required to protect the health and future of all children and their common home.

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ABBREVIATIONS

AAP: American Academy of Pediatrics
CO_2: carbon dioxide
EHI: exertional heat illness
GHG: greenhouse gas
HFMD: hand, foot, and mouth disease
HRI: heat-related illness
$PM_{2.5}$: particulate matter less than 2.5 microns
PTSD: post-traumatic stress disorder

The guidance in this report does not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

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