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Climate Change, Excess Heat, and Health

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Climate Change, Excess Heat, and Health

Background and Problem Statement

Climate change is undeniably present, worsening, and anthropogenic (1). The current carbon levels in our atmosphere are the highest they've been since the Pliocene epoch over 3 million years ago (2). More alarmingly, the pace of this carbon pollution is accelerating despite increasing attention and acceptance that this is a real problem, with CO2 emissions in 2015, 51% higher than they were in 1990 (3). The United Nations' Intergovernmental Panel on Climate Change (IPCC) has stated that as of 2022, we are on path to exceed the 1.5 degree "red line" that was agreed at the Paris Accords in 2015 (4).

Its effects will touch every single facet of our biosphere and human experience, from changing ocean currents to reduced agricultural output to depleted biodiversity and frequent extreme weather events (5). According to the latest Intergovernmental Plan on Climate Change (IPCC) (2021), for 1.5 degrees Celsius of global temperature increasing, we will see intensifying heat waves, longer warm seasons, and shorter cold seasons. At 2 degrees Celsius, heat extremes would frequently reach critical tolerance thresholds for agriculture and human health (6).

Climate Change and Excessive Heat

A particular worrisome effect of climate change on human health and welfare will be its effect on the creation of deadly heat waves (7). Heat waves are increasing in frequency and intensity and undeniably related to climate change processes. There's a direct link between climate change and deadly heat waves. A study by the World Weather Attribution looking at the deadly 2017 Southern European heat waves, found that climate change increased its chance of occurrence by a factor of 10. (8) A study by the Union of Concerned Scientists in 2019 found that by middle of the 21st Century, the United States will see the number of days with 105-degree heat index temperatures to triple (9) and another study in 2017 found that for every 1 degree Celsius of increased global warming, we will see the number of heat-wave days increase from 4 to 34 days per season (10).

This increased frequency of heat waves is being observed now, from an average of two heat waves a year in the 1960s to six a year in the last 10 years. They are also lasting longer: an average of four days now, compared to an average of three days in the 1960s. The intensity has increased in lockstep with this change in frequency. In the 1960s, an average heat wave was 2.0 degrees Celsius above the 85th percentile threshold. In the last decades, they have averaged 2.3 degrees Celsius above the threshold (11).

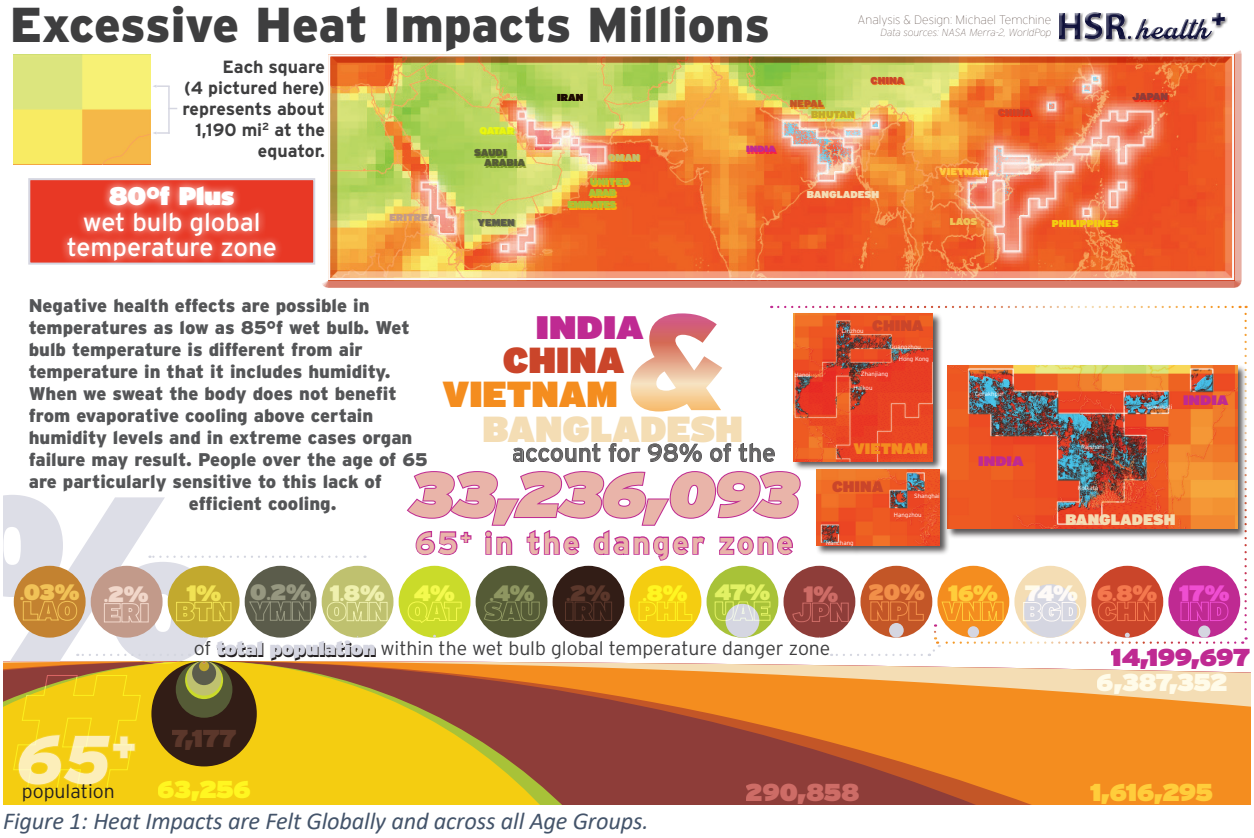

Figure 1: Heat Impacts are Felt Globally and across all Age Groups.

How Excessive Heat Affects Human Health

Exposure to heat – prolonged exposure to solar radiation and atmospheric temperatures without opportunities for cooling, including for example, shade, can have a devastating effect on human wellbeing in both direct and indirect ways impact the health of our bodies in a myriad of ways.

Direct Effects

Human health can be directly impacted by excessive heat in the following ways:

Heat exhaustion and heat death

- The most obvious and direct cause of harm from excessive heat is the morbidity and mortality created by the direct effect of heat on human bodies. Heat waves are routinely some of the deadliest natural disasters known with heat waves killing twice as many Americans as tornadoes (12).

- The mortality secondary to heat waves is now frequently reaching into the many tens of thousands. The European heat wave of 2003 for example, is estimated to have caused 70,000 deaths (13) and the heat waves that struck Russia in 2011 killed about 56,000 Russians (14).

- Such deadly heat waves engulfing multiple countries has become routine in the last decade. There were heat waves lasting for days at a time and killing thousands in the United Kingdom (2018), United States (2018), Japan (2018), Australia (2019), India (2019), Pakistan (2019), the European Union (2019) and India (2022) among many others (15).

Acute kidney injury and chronic kidney disease

- Excessive heat and subsequent dehydration is a major contributing factor to acute kidney injuries (AKIs) which have become epidemic among workers who toil outdoors throughout the planet and are exposed to frequent and ever more intense heat waves (16).

- A study done in California showed that 12% of farm workers developed signs of kidney injury over the course of just a single day exposed to unrelenting heat (17).

- In Central America alone, we have seen a spike a chronic kidney disease (CKD) and eventual kidney among sugarcane workers in Central America, with CKD prevalence rising tenfold in men and fourfold in women since the 1970s (18) and over 20,000 workers dying of renal failure as of 2021 (19).

Mental health effects

- Excessive heat has a palpable and measurable effect on mental health as well with heat waves affecting mood disorders, anxiety disorders, dementia, alcohol and drug misuse and suicidal behavior (20) as well as worsening symptoms of schizophrenia in both outpatient and inpatient settings (21).

- Rising temperatures and humidity are related to increased emergency room visits for mental health effects (22) and increased admissions to psychiatric hospitals (23).

- Heat also highly correlates with interpersonal violence and conflict between people. Multiple studies have shown positive associations between rising temperatures and increase in intentional homicides, sex offenses and assaults (24).

- Excessive heat has also been shown to affect learning potential, with research showing an average temperature increase of just 0.55 degrees Celsius over a year resulted in a 1% decrease in learning and an accumulated $25,000 in lost earnings for the students affected (25) and a one-standard-deviation increase in temperature during the exam period within counties (2 °C/3.6 °F) decreasing total test scores by 0.68% (26).

Indirect Effects

Excessive heat can also affect human health through its indirect effects. Discussed below, these effects can be longer term and therefore harder to tie to instances of extreme heat and potentially harder to mitigate.

Oceanic processes

- Heat waves are just as deadly when they occur on oceans, leading to massive die offs of marine species as well as the destruction of fragile marine ecosystems such as coral (27).

- This has a devastating effect on biodiversity which particularly impacts sea-based economies and nutrition of oceanic origins which account for a sizable amount of the nutrition intake of much of the world's population.

- Increasing heat and subsequent increased ocean temperatures have also been correlated with the increase in harmful algal blooms (28), increased ocean acidification (29) and increase in both the intensity and frequency of extreme weather of oceanic origin such as hurricanes and typhoons (30).

Agricultural output, animal husbandry and human nutrition

- High temperatures have been shown to lead to decreased photosynthesis, leaf senescence, decreased pollen production and pollen viability, seed abortion, and consequently lower grain

number and grain weight, particularly in some of the world's most important crops such as soy, sorghum and wheat, creating the possibility of lower yields, food shortages and global hunger (31).

- Excessive heat stress effects on domesticated animals include reduced milk productivity, reduced fertility, increased susceptibility to disease, and increased mortality (32).

- Direct heat waves effects can also lead to massive mortality among animal species important for human nutrition with a recent heat wave in Kansas estimated to have killed 10,000 heads of cattle across the state after 4 days of continues > 104 degree heat (33).

Bacterial infection risk and antimicrobial resistance

- Horizontal gene transfer, a major mechanism for the acquisition of antibiotic resistance, is increased by increasing temperatures. In addition, increases in temperature generally increase bacterial growth rates (34).

- Increases in temperate are associated with increases in bacterial infections. An international study of 22 cities found that proximity to the equator and socioeconomic factors were both positively associated with risk of Gram-negative bacteremia (35).

- Increase in local temperatures is associated with antibiotic resistant infections. An increase in temperature of 10 °C across regions was associated with an increase in antibiotic resistance of 4.2%, 2.2%, and 2.7% for the common pathogens *Escherichia coli*, *Klebsiella pneumoniae* and *Staphylococcus aureus* (36).

Vector-borne disease risk

- Rising temperatures are well known to favor the growth in populations of multiple vectors known to carry disease, such as mosquitos and ticks. As temperatures increase, the range of many vectors also gets larger, increasing the number of susceptible individuals (37).

- In the United States alone, mosquito season has grown by 76% in major cities since the 1980s due to increases in average temperatures (38).

- It is estimated that given current climate change and increasing heat projections, the range of *Aedes aegypti*, an invasive mosquito vector for many arboviruses such as dengue, zika and yellow fever, will expand 2-6 km per year in the next 30 years (39).

- Further modeling shows that given current warming trends, 8.4 billion people, or 90% of the projected population, will be at risk for dengue infection in 2080 due to expanded vector ranges (40).

Wildfire risk

- Heat waves considerably increase the risk of wildfires. Short term droughts and heat waves dry out vegetation, creating perfect conditions for easy ignition and fire propagation (41).

- Wildfires have been increasing in intensity and frequency, with significant subsequent damage to human populations, both directly through fire damage and physical burns, as well as well indirectly through smoke production and inhalation, which has been shown to increase all-cause morbidity and mortality, beyond even respiratory causes (42).

The Future and What HSR.*health* Offers

There does not seem to be hope that climate change effects can be prevented considering the lack of political will and momentum at the moment. We need to move from a vision of prevention and embrace planning for emergency preparation and mitigation.

Geospatial science and analytics present a particularly useful tool for this mitigation activity. The ability to visualize geographical areas under threat and populations at particular risk from often-deadly climate change processes will be an incredibly valuable asset to any locality under siege from our changing planet.

HSR.*health* is at the forefront of geospatial health analytics as a tool for furthering improvements in human welfare and life-saving strategic planning. We are an innovation-first healthcare technology firm and the leading provider of geospatial health risk analytics. Our AI-enabled, geospatial platform curates data globally and provides actionable health risk insights throughout the healthcare ecosystem as well as to broader markets.

As such, we can assist with emergency plans for our eventual heat wave scorched future by:

Identification of Vulnerable Populations

While a warming planet will eventually expose all of humanity to rising heat, distinct heat waves, often creating deadly conditions within a very short amount of time, will affect different areas of the planet at different times and in different ways. We can pinpoint particular areas at risk for severe heat waves, populations whose intrinsic vulnerabilities place them at the highest risk for elevated heat-related morbidity and mortality and social and geographic factors, like wildfire risk and low cooling center density, that could augment the ultimate harm.

> *Ex: Among the population in a given province affected by a heat wave, which city and which neighborhoods are at the highest risk for hospitalization secondary to dehydration and lack of cooling resources?*

Quantifying the Risk of Negative Health Outcomes

It is a sobering reality in healthcare that we simply never have enough resources to ensure complete coverage of a given population or geographical area. Therefore, it is of the utmost importance that we can triage populations according to their current emergency need. The ability to quantify health outcomes and hierarchize in order of severity and threat to life is key in any strategic planning activity.

> *Ex: Among the population in a given city affected by a heat wave, which age cohort is at the highest risk for hospitalization secondary to heat-related renal failure?*

Analyzing the Effect of Multiple Natural Processes on One Outcome

Health effects from natural processes are often the result of a complex mélange of natural forces, pre-existing social and economic vulnerabilities and current mitigation capacity. We are able to parse out and identify the magnitude in which different social determinants of health (SDOH) as well different natural process thresholds will affect health outcomes.

> *Ex: How does housing and air quality combine to influence the risk of hospitalization for adults in high heat risk areas? What happens when race is added to the analysis?*

Facilitate Strategic Mitigation and Emergency Plans

As touched upon before, the reality of scarce resources necessitate a clinical and methodical approach to intervention in natural disaster areas. There is a need-to-know which region to concentrate rescue efforts on first and which population groups within that region to prioritize in relief activity. No emergency preparedness plan can consider itself complete without an a priori geographical analysis of relief intervention priority.

> *Ex: Where should we place strategic emergency generator stockpiles for use in powering cooling centers when heat waves occur?*

Conclusion

Climate change is likely to be the greatest challenge our species has faced since the end of the Ice Age. Its myriad, complex and interrelated attacks on human welfare will require multidisciplinary efforts and innovative thinking. We believe our capabilities are a perfect fit to assist any government or organization that wants to tap human ingenuity and technological innovation to save lives and prepare for worst case scenarios.

HSR.*health* believes in the power of science and data to change the world. As global challenges relating to climate change, excessive heat and health inequity spread through the globe, it is our firm conviction, that through the scientific application of ingenuity, the most complex problems can be solved.

HSR.*health* wants to meet these challenges and through our methodical analysis and actionable tools, be a part of the grand movement working right now in partnership with dozens of organizations around the planet to prepare our greater human family to face this great unknown.

Our approach allows for a methodical analysis and study of vulnerable areas and populations of our planet so that strategic interventions can be deployed for maximum effect. Our tools will empower communities at greatest risk to extreme heat better prepare for natural disasters and minimize the damage, both in lives and property, that these can bring.

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