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The Role of Cooling Centers in Protecting Vulnerable Individuals from Extreme Heat

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The June 2021 record-breaking heat wave across the US Pacific Northwest and western Canada highlights the challenges faced by governments, communities, public health, and health care practitioners around the world to protect the public against the threats associated with continued climate change.[1] Of course, the US is not the only country experiencing these record-breaking temperatures. Globally, the past decade was the warmest on record.[2] This summer Canada recorded their highest temperature ever and 23 additional countries experienced highs over 121°F.[3] Extreme heat events are projected to become more frequent and severe with continued climate change, and public health efforts are appropriately focused on helping communities and individuals better prepare for such events.[4–7]

Although the health risks posed by days of extreme heat are well documented, much uncertainty remains regarding which population-level interventions are most effective in reducing the burden of disease or how to optimally deploy these interventions at scale.[8–10] For example, although the implementation of heat early warning systems and heat response plans appears to reduce the morbidity and mortality associated with days of extreme heat,[11–13] there is little agreement as to what are the essential features of such plans.[14–16] Moreover, exposure, susceptibility, and adaptive capacity are unequally distributed both within and between communities, suggesting that generic interventions not specifically customized to address local needs are unlikely to be optimal. Thus, further research is needed to inform present-day and future efforts to effectively reduce heat-related morbidity and mortality, with a particular emphasis on identifying and protecting the most vulnerable communities and individuals.

At the individual level, air conditioning provides the most obvious protection against the adverse health impacts of extreme heat, but access to air-conditioned spaces is far from

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ubiquitous, particularly in more northern latitudes.[17,18] For example, according to the 2019 American Housing Survey, 56 percent of residents in Seattle, Washington and 22 percent of residents in Portland, Oregon do not have air conditioning at home.[17] Air conditioning can be provided in multiple settings, including homes, places of work, and public spaces. In the Pacific Northwest, cooling centers became an important place to seek refuge from the heat for at least some of the hundreds of thousands of residents that do not have access to air conditioning in their homes or place of work.[17,19] Cooling centers are a common, low-cost extreme heat intervention,[20] currently being used in many major cities in the US and abroad under the common-sense premise that providing refuge from the heat and distributing water to the public at these locations during heat events helps reduce the risk of heat-related morbidity and mortality. However, this intervention deserves further scrutiny in order to determine how to optimize its effectiveness and guide appropriate implementation.[20]

Numerous studies have evaluated the equitable placement of cooling centers to target vulnerable populations, but there is little evidence on how many people use or benefit from cooling centers and how effective cooling centers are in reducing heat-related morbidity and mortality.[20,21] Maricopa County, which encompasses Phoenix, Arizona, has one of the most comprehensive cooling center systems in the US, with more than fifty locations serving a population of nearly 5.5 million. Yet, a study conducted in the summer of 2014 found that 27% of these facilities were filled at 5% capacity or less and only 3% of registered cooling centers reported being near capacity on a daily basis.[22] Similarly, the six designated cooling centers in Los Angeles, California saw fewer than 11 people per center per day during a heatwave over Labor Day weekend in 2020.[23] These examples suggest that at least in these locations, availability of cooling centers is not a limiting factor in the success of this intervention, although accessibility or other constraints may lead existing cooling centers to be underused. Thus, there seems to be a discrepancy between the enthusiasm of public health officials to open cooling centers during periods of extreme heat and a decided lack of enthusiasm or ability by the public to take advantage of these resources.[24]

So, what are the key barriers preventing more people from taking greater advantage of designated cooling centers during episodes of extreme heat? We posit that barriers to wider adoption can be classified as being related to awareness and motivation and to access and opportunity.

Awareness and Motivation

Some individuals may not be aware of the threat posed by extreme heat while others may not be aware that there are interventions (such as cooling centers) available that can help lower their risk of adverse health outcomes. Other individuals may not believe that they are at risk themselves.[20] For example, one study found that, while elderly people are amongst the most vulnerable to the effects of extreme heat, they also were least likely to perceive themselves as such.[20] This trend extends to the general population as well, where surveys have illustrated that despite widespread awareness of heat advisories, there is rarely a shift in behavior — most often attributed to “a lack of self-perception as vulnerable and confusion about the appropriate actions to be taken”.[24] There is also the question of motivation, a recurrent theme in health behavior theories; awareness is a major component, but other factors include attitudes, intentions, social support, and self-efficacy.[20] Many individuals may elect not to use cooling centers because they prefer to remain in their own homes, places of work, or other public and private spaces where they can cool off.[9] Others may opt to remain home as opposed to visiting cooling centers because they worry they would not have anything to do while visiting or because of a perceived stigma associated with attending cooling centers.[20]

Access and Opportunity

Other individuals may be aware that such resources are available but may not be able to access them for various reasons. Many vulnerable individuals may not have the time or opportunity to visit a cooling center due to work or other commitments. For example, using cooling centers may not be a realistic option for outdoor workers, a highly exposed population in which other cooling interventions have been explored.[25] Even individuals who could spend time at a cooling center may find it inconvenient or impossible to get to one. Despite generally being placed relatively closer to populations perceived to be more vulnerable, there is significant heterogeneity in the number of cooling centers per city and their location.[21] For example, some homeless or elderly individuals may not have the means to get to a cooling center, or may have pets or require medical equipment that are impractical or impossible to bring to a cooling center. Moreover, certain cooling center locations may be perceived as unwelcoming by some members of the community. For example, cooling centers located within police stations may discourage some people from visiting. Awareness of the risks, awareness of the available resources, and access to these resources is not sufficient; individuals must also have the opportunity to use cooling centers, many of which operate only during daytime or business hours.

Given these potential barriers to access and the limited empirical evidence available suggesting low usage, we sought to estimate how many people would need to visit a cooling center on a day of extreme heat in order to prevent one heat-related death that day: an analogue of the number needed to treat (NNT). Our estimate of the NNT — a well-recognized clinical measure of the number of people who must receive an intervention in order to avert one specified adverse outcome over a given period of time — is simplistic and meant only to illustrate a point. For simplicity, we made the following four assumptions: (1) all deaths attributable to extreme heat occur on the same day as the extreme heat (i.e., no lagged effects); (2) when the excess number of deaths attributed to days of extreme heat are reported on an annual or seasonal basis rather than per day, we assumed that there are ten days of extreme heat each year in any given location; (3) visiting a cooling center on a day of extreme heat reduces the risk of heat-attributable death by 66%, a relative risk reduction for those with air conditioning exposure as compared to those without;[26] and (4) the risks of extreme heat and the benefits of visiting a cooling center are independent across days and individuals.

In every version of the above calculation, with varying geographical location and time period over which deaths were recorded, the estimated NNT is enormous. Specifically, to prevent one heat-related death on a single day of extreme heat, millions of people would have to visit a cooling center on that one day. This is, in part, because the absolute risk of death or illness (i.e., the event rate) on any day in the general population is low. The excess risk associated with extreme heat is substantial when aggregated across a population but small for any given individual on any given hot day.

Comparing rows 2 and 3 of the Table highlights how much the NNT can vary depending on the underlying estimate of the absolute excess risk associated with a day of extreme heat. Specifically, the CDC estimates of heat-attributable excess deaths is based on counting death certificates in which heat is identified as a contributing cause while the estimates by Weinberger et al. are estimated based on statistical excess deaths.[29] This latter approach leads to much higher estimates of absolute excess risk and thus a much lower NNT. The NNT is also impacted by the effectiveness of the intervention (here, visiting a cooling center) in reducing the risk of an adverse outcome. In this illustration, we assume that visiting a cooling center reduces the risk of heat-attributable death by 66% as reported in a published meta-analysis.[26] The NNT would be somewhat smaller if we assumed a greater degree of risk reduction and grow towards infinity if we assume that cooling centers are completely ineffective in preventing heat-related health outcomes.

We would expect the NNT to be lower in locations, populations, or settings where the baseline or excess risk is higher (e.g., places with low air conditioning prevalence). We also recognize that the NNT would be substantially lower – likely by orders of magnitude – among individuals at particularly high risk, highlighting the need to focus any interventions on the most vulnerable individuals. Regardless, we expect that the NNT would likely be very high even in at-risk communities and amongst the most vulnerable individuals, though it may begin to approach a range considered relevant for large public investments in interventions to benefit health in other contexts.[32]

Of course, death is not the only adverse health outcome of heat worth averting. We repeated the calculations under the generous assumption that the risk of heat-related illness is either ten or one hundred times greater than that of heat-related death, and assuming that cooling centers could reduce the event rate of emergency department (ED) visits in the 2006 California heat wave by 66%. Still the estimated NNT is remarkably large, though subject to the same considerations above, (i.e., that an intervention targeted at a high-risk subset of the population would substantially lower the NNT). Under the above assumptions, the NNT on a single day of extreme heat in order to avert one heat-related death, heat-related hospitalization, or ED visit is far higher than the apparent number of daily visitors to cooling centers in the US. It is important to note that we have limited data on the population who visit cooling centers that do not otherwise have access to cooling services; so further understanding of the extent to which air conditioning and other heat-related interventions are accessible to the entire community, and how the gaps in access can be closed, is essential.

More broadly, these estimates suggest that cooling centers cannot be the only or even the central adaptive intervention in a city’s extreme heat response plan. Even assuming that cooling centers reduce the absolute risk of heat-related mortality on a given day, an unfeasibly large number of people would have to visit these centers in order to actually reduce the number of observed heat-related deaths. Thus, cooling centers must be recognized as only one of many extreme heat interventions. Nonetheless, cooling centers do serve as an important component of a city's extreme heat adaptation measures – particularly for the relatively few individuals who use them. And the NNT calculations highlight the benefits of identifying and reaching those individuals at highest risk and lowering barriers to cooling center access.[26]

A wide range of other adaptive measures are commonly used as part of the acute heat response, including distribution of window air conditioning units to vulnerable populations, energy assistance for residential cooling, establishing alternate working hours for outdoor workers, increasing transportation services during heat-waves, evacuating long-term care facilities or ensuring they have effective air conditioning, distributing drinking water throughout public facilities (including bus and train stops), and suspending utility shutoffs.[16,33] Although all seemingly reasonable approaches, there is surprisingly little evidence regarding which interventions are most effective in which settings. As noted by Professor Kris Ebi of the University of Washington, "one-size-fits-all approaches are less effective than solutions designed (preferably co-designed) and implemented with local stakeholders".[34]

Indeed, intervention effectiveness is a pressing knowledge gap that would benefit from additional research at the intersection of epidemiology and implementation sciences and in partnership with local stakeholders. For example, Benmarhnia et al. evaluated the health benefits associated with implementation of a new heat action plan in Montreal and revision of a heat action plan in New York City.[11,35] A number of other examples can be found in the published literature (e.g. [12,13,36,37]), but we still lack the insights needed to optimize population-level interventions in any given location or population. Not all good ideas will prove to be effective, not all interventions that seem promising will be scalable to the population level, and many solutions that work well in one setting may not perform as well in others. Future studies should seek to provide more nuanced insights into who is at greatest risk of heat-attributable events, how to most effectively communicate that risk to vulnerable individuals or their advocates, and which recommended actions by individuals, communities, or government officials are most effective in reducing heat-related morbidity and mortality in specific contexts. Answering these questions in a context-specific manner will require substantial innovation in terms of both data and approaches, cross-disciplinary collaborations, and meaningful engagement with key stakeholders. And continued evaluation will be needed as new interventions are implemented in order to guide future investments in the most cost-effective solutions.

While air-conditioning use will remain a necessary adaptation to extreme heat, in the long-term, increased access to air conditioning needs to be accompanied by other complementary adaptive measures that serve to reduce exposures and vulnerability on days of both moderate and extreme heat. In addition, air conditioners of the near future will need to be much more energy efficient and powered by green energy in order to not further exacerbate the pace of climate change.

In short, we recognize the value and importance of cooling centers as a key feature of heat response plans, but also note their limited potential benefit in the absence of additional heat adaptation measures and targeted risk reduction strategies focused on high-risk groups.

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Data Availability:

All the data used in this commentary are derived from sources in the public domain, as referenced.

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Table –

Estimated number needed to treat (NNT) for cooling centers under various assumptions and scenarios. The NNT estimates how many people would need to visit a cooling center on a single day of extreme heat in order to prevent one heat-attributable death that day. Note that lower absolute risks imply a higher NNT. We assume that visiting a cooling center reduces the risk of heat-attributable death by 66%. See text for additional assumptions.

Scenario	Heat-Related Outcome	Absolute Risk of Outcome on Extreme Heat Day (per million people) [a]	NNT
Excess deaths in Maricopa County, Arizona[b]	Death	0.92	1,648,868
Excess deaths in US (CDC data)[c]	Death	0.15	9,900,990
Excess deaths in US (Weinberger et al. 2020)[d]	Death	3.45	439,222
Excess Extreme-Heat Related Deaths in Europe[e]	Death	0.52	2,890,011
If Risk of Heat-Related Illness is 10x that of Heat-Related Death[f]	Illness	1.53	990,099
If Risk of Heat-Related Illness is 100x that of Heat-Related Death[f]	Illness	15.3	99,010
Excess emergency department visits in California[g]	Illness	25.0	60,606

[a]Unless otherwise noted, we assume that any given location experiences 10 days of extreme heat per year. This assumption influences the estimation of the absolute risk of heat-attributable events per day from published reports.

[b]Based on CDC data on heat-related mortality for Maricopa County for 2000 to 2019 and average population across the same time period,[27] and assuming ten days of extreme heat per year.

[c]Based on 2019 CDC Data[27] and assuming a population size of 330,000,000 and ten days of extreme heat per year.

[d]Based on Weinberger et. al, which estimated the number of deaths attributable to extreme heat in the 297 most populous counties in the United States (accounting for ~62% of the national population). This study defined a day of extreme heat as one in which daily maximum temperature reached or exceeded the 97.5th percentile of the local warm season (May – September in the norther hemisphere) temperature distribution, or an average of 3.825 such days per year in any given location.[29]

[e]Based on extreme-heat fatalities data reported from the Joint Research Centre of the European Union,[30] and an estimated population of 515,000,000.

[f]Based on the estimates from row 3.

[g]In the 2006 California heat wave, there were 16,164 excess emergency department visits over 18 days in a population of 35,950,000, yielding an event rate of 25.0 excess visits per million people per day.[31]