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Heat vulnerability of Latino and Black residents in a low-income community and their recommended adaptation strategies: A qualitative study

Kevin Lanza[a,*], Jessica Jones[b], Frances Acuña[c], Marc Coudert[d], R. Patrick Bixler[b], Harsh Kamath[e], Dev Niyogi[e,f]

[a] The University of Texas Health Science Center at Houston, School of Public Health in Austin, 1616 Guadalupe St, Suite 6.300, Austin, TX 78701, USA
[b] University of Texas at Austin, LBJ School of Public Affairs, 2315 Red River St, Austin, TX 78712, USA
[c] Go Austin/Vamos Austin, 3710 Cedar St, #230, Austin, TX 78705, USA
[d] City of Austin, Office of Resilience, 301 W 2nd St, Austin, TX 78701, USA
[e] University of Texas at Austin, Jackson School of Geosciences, 23 San Jacinto Blvd, Austin, TX 78712, USA
[f] University of Texas at Austin, Cockrell School of Engineering, 301 E Dean Keeton St, Austin, TX 78712, USA

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ABSTRACT

Latino, Black, and economically disadvantaged individuals in the U.S. have been shown to disproportionately live in areas characterized by urban heat islands, yet little qualitative data exist to inform heat adaptation. In a low-income community of color, we explored residents' heat-related health and well-being outcomes, heat vulnerability, and recommended adaptation strategies. From July–September 2021, we conducted qualitative interviews with 18 economically disadvantaged adults (female = 17, Latino = 16, Black = 2) in an area with high urban heat island intensity in Austin, Texas. We identified six themes using NVivo. First, heat impacted residents' physical health (fatigue, headaches, nausea, dizziness, trouble breathing), mental health (uncomfortable, stress), physical activity, and social relationships. Second, heat exposure was only mentioned outdoors (active transportation, outdoor work, recreation). Third, residents perceived children and those with diabetes and hypertension as most sensitive. Fourth, adjusting to heat included staying home, drinking liquids, changing schedules, and using air conditioning. Fifth, barriers to adjusting to heat were lack of trees, shade, greenspace, and bluespace, along with electricity cost and power outages. Sixth, residents recommended adding trees, shade structures, parks, pools, splash pads, and drinking fountains. Findings complement quantitative data to support municipal efforts in designing equitable, heat-resilient cities.

Abbreviations: GPS, Global Positioning System; N.D., No Date; U.S., United States; ZIP Code, Zone Improvement Plan Code.

* Corresponding author.
E-mail addresses: Kevin.L.Lanza@uth.tmc.edu (K. Lanza), j.m.jones@utexas.edu (J. Jones), frances@goaustinvamosaustin.org (F. Acuña), Marc.Coudert@austintexas.gov (M. Coudert), rpbixler@utexas.edu (R.P. Bixler), harsh.kamath@utexas.edu (H. Kamath), dev.niyogi@jsg.utexas.edu (D. Niyogi).

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1. Introduction

High ambient temperatures are a major public health concern. In the U.S., an average of 702 heat-related deaths occurred each year from 2004 to 2018 (Vaidyanathan et al., 2020), significantly more deaths than all other weather-related hazards (U.S. National Oceanic and Atmospheric Administration, n.d.). Yet this analysis was based on cause of death, which researchers warn may substantially underestimate the total burden of heat-related mortality (Weinberger et al., 2020). For instance, a study of 12 major metropolitan areas across Texas revealed that high temperatures significantly impacted all-cause mortality (Guo et al., 2023). Along with mortality, high temperatures have been shown to increase morbidity and adverse pregnancy outcomes, as well as negatively affect mental health (Ebi et al., 2021). Heat has also been identified as a barrier to using public transit (Lanza and Durand, 2021) and engaging in other forms of physical activity (Koepp et al., 2023; Lanza et al., 2022a,b), a health behavior that reduces chronic disease risk, among other benefits (U.S. Centers for Disease Control and Prevention, 2022). The negative impact of heat on health is expected to grow, as climate change is increasing overall temperatures and the intensity, frequency, and duration of heat waves (Hayhoe et al., 2018; Smith et al., 2013).

Protecting individuals from rising temperatures requires an understanding of societal vulnerability to heat, often conceptualized as three components: exposure, sensitivity, and adaptive capacity (Adnan et al., 2022; Wilhelmi and Hayden, 2010). The Intergovernmental Panel on Climate Change defines exposure as the presence of people in places and settings that could be adversely affected; sensitivity as the degree to which people are affected, either adversely or beneficially; and adaptive capacity as the ability of people to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2022).

A multitude of quantitative studies have focused on heat vulnerability to inform the design of climate adaptation strategies (Adnan et al., 2022; Cheng et al., 2021; He et al., 2022), defined as actions to prepare for and adjust to both the current and projected impacts of climate change (U.S. Environmental Protection Agency, 2022a). Individuals living in cities are generally exposed to higher ambient temperatures than those living in surrounding areas due to the urban heat island effect, a phenomenon driven by high amounts of impervious materials, lack of vegetation, waste heat emissions from industrial processes, and urban form (Stone Jr. et al., 2019). Factors affecting indoor heat exposure include the presence of a working central air-conditioning system, other residential building characteristics, and presence of nearby tree canopy (Larsen et al., 2022). Populations identified as sensitive to heat comprise older adults, children, women, those with pre-existing medical conditions, people who lack awareness of climate change effects, and economically disadvantaged individuals (Osberghaus and Abeling, 2022; Benmarhnia et al., 2015; Son et al., 2019; Greaney et al., 2016; Zander et al., 2017). To adapt to heat, individuals have reported staying indoors, drinking water, using air conditioning, and avoiding outdoor activity (Hayden et al., 2017).

The overwhelming majority of studies on heat vulnerability employ quantitative over qualitative approaches (Gonzalez-Trevizo et al., 2021; Karanja and Kiage, 2021), with the latter helping us understand why and how certain populations are more vulnerable than others. Data from qualitative studies can provide locally-relevant context that is crucial to the implementation of effective adaptation strategies (Ellena et al., 2020), and help safeguard against maladaptation (i.e., actions that increase the risk of adverse climate-related outcomes) (IPCC, 2022). While studies on heat vulnerability purport to assist decision-makers in protecting human health and well-being, many do not incorporate direct and meaningful engagement from those affected (Preston et al., 2011).

Of the few qualitative studies on heat vulnerability ($n = 9$), most have focused on older adults (Abrahamson et al., 2009; Banwell et al., 2012; Eady et al., 2020; Hansen et al., 2011; Jonsson and Lundgren, 2015) and/or occurred in geographic locations characterized by cold or temperate climates (Abrahamson et al., 2009; Eady et al., 2020; Hansen et al., 2011; Jonsson and Lundgren, 2015). The majority of qualitative studies occurring in warm climate regions explored the heat vulnerability of specific populations including outdoor farm laborers in South Africa (Mathee et al., 2010), residents in urban informal settlements in Tanzania (Pasquini et al., 2020), and individuals considered particularly knowledgeable about institutional, socio-economic, and cultural constraints and determinants of adaptive capacity to heat waves in Sydney, Australia (Zografos et al., 2016). The lone qualitative study based in the U.S. investigated the adaptive capacity to extreme urban heat of a largely White sample of adults in the subtropical desert climate of Metropolitan Phoenix, Arizona (Guardaro et al., 2022). Only Jonsson and Lundgren (2015) collected qualitative data on heat adaptation strategies at the societal level (e.g., urban design, targeted warnings, community-based programs).

In this qualitative study, we used an inductive approach to explore the heat-related health and well-being outcomes, heat vulnerability, and recommended adaptation strategies of economically disadvantaged Latino and Black adults who live in a portion of a U.S. city characterized by an urban heat island. Heat is a health inequity in the U.S.: low-income communities and communities of color experience relatively higher levels of ambient temperature due to discriminatory policies (e.g., redlining) and ongoing disinvestment (Hoffman et al., 2020). Study findings can provide essential information for experimental studies of specific heat adaptation strategies that safeguard those whose lives are unfairly impacted.

2. Materials and methods

2.1. Study setting and sample

This qualitative study took place in the humid subtropical climate of Austin, Texas, U.S., a city spanning 829km^2 (320mi^2) and home to approximately 960,000 residents, in 2020 (U.S. Census Bureau, n.d.). From 1991 to 2020, temperatures in the city reached above 33 °C (91 °F) from June–September, on average, with the warmest month of August reaching 37 °C (98 °F), on average (U.S. National Weather Service, n.d.). This study was part of a research project funded by the National Oceanic and Atmospheric Administration (NA21OAR4310146) in which academics, non-profit organizers, and city officials took a mixed methods approach in support of community resilience to heat in Austin. The project stemmed from the Urban Heat Watch program, wherein local volunteers measured heat by driving their personal vehicles—equipped with air temperature and relative humidity sensors and GPS devices—on 12 street routes located in the eastern half of Austin during morning (6:00–7:00), afternoon (15:00–16:00), and evening (19:00–20:00) on August 7, 2020 (CAPA Strategies, 2020). In situ measurements covered only a 303km^2 (117mi^2) portion of Austin due to resource constraints preventing measurement across the entire city. The local research team decided to measure temperatures in East Austin because it included the "eastern crescent", an area of Austin shaped like a backward letter "C" that has faced decades of disinvestment in part due to publicly-supported racial and ethnic segregation (University of Texas at Austin, 2023). As final output from the Urban Heat Watch program, researchers integrated the collected ground measurements with satellite imagery in a Random Forest regression model to predict a spatially continuous temperature map for each of the three measurement periods (Shandas et al., 2019).

We concentrated recruitment of study participants in a historically redlined area of the city facing ongoing disinvestment (University of Texas at Austin, 2023) that had higher urban heat island intensity than other parts of East Austin (CAPA Strategies, 2020) (Fig. 1). Recruitment spanned three ZIP Codes (78,752, 78,753, 78,758) with lower proportions of White residents, higher proportions of Hispanic/Latino residents, lower median household income, and higher proportions of residents below the federal poverty level compared to the City of Austin (U.S. Census Bureau, 2022a, b, c) (Table 1). Leveraging their deep social roots in these ZIP Codes, Go Austin/Vamos Austin—a coalition of neighbors and community partners breaking down barriers to healthy living and strengthening neighborhood stability in the Eastern Crescent—used snowball sampling by word of mouth to recruit a convenience sample of adults ($n = 18$). This sample size was based on reaching data saturation after 18 interviews where no new themes emerged in explaining heat-related health and well-being outcomes, heat vulnerability, and adaptation strategies, which aligns with results of a systematic review of qualitative studies that assessed sample sizes for saturation (Hennink and Kaiser, 2022). Study participants consisted of 17 females and one male, 16 individuals identifying as Latino and two as Black, and 14 individuals choosing Spanish language for study participation. All had mentioned their hardship in getting their needs met. Prior to conducting any study activities, the institutional review board at The University of Texas at Austin reviewed and approved project protocols.

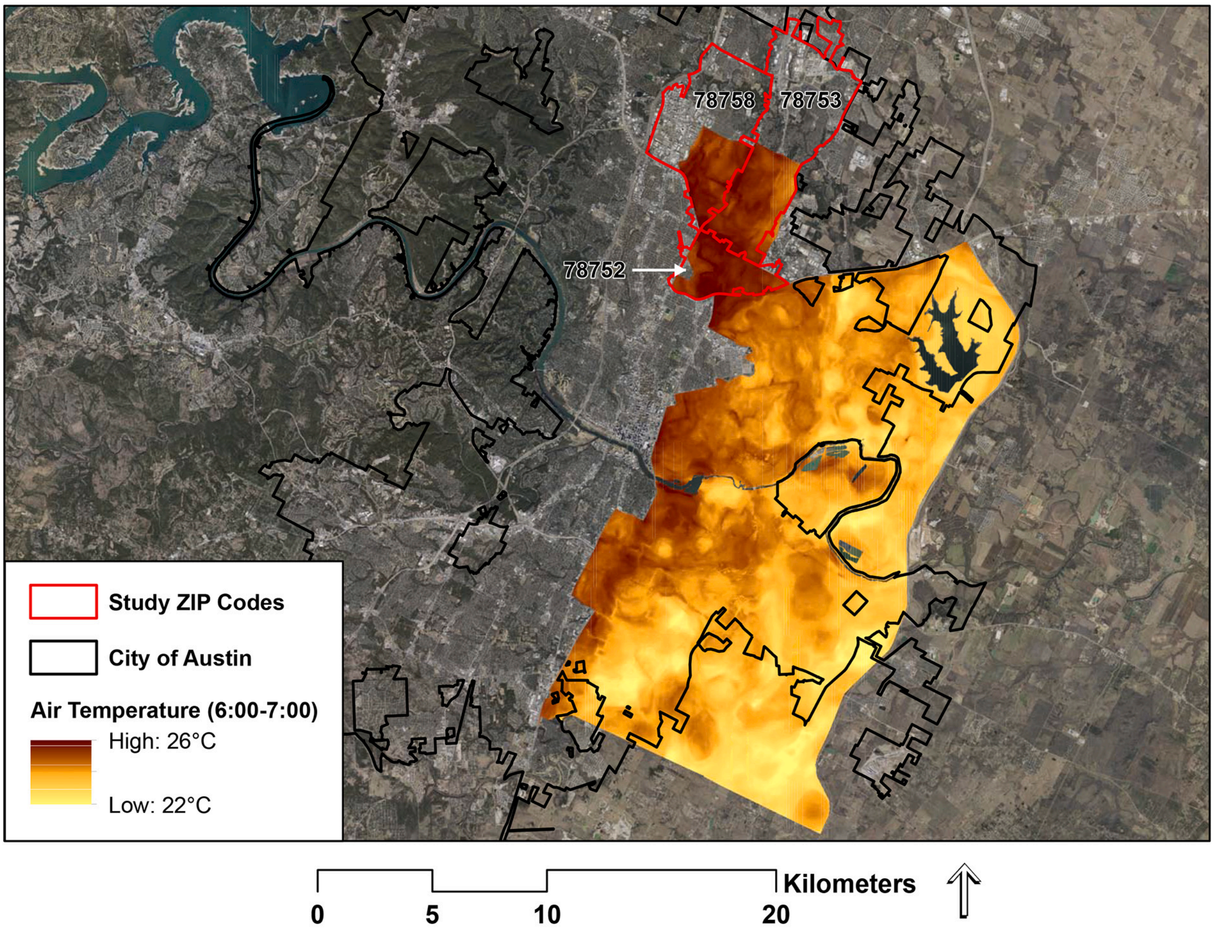

Fig. 1. Modeled air temperature in the morning (6:00–7:00) of August 7th 2020 across a 303km^2 portion of Austin, Texas, with a focus on study ZIP Codes.

Table 1
Select sociodemographic characteristics of residents in study ZIP Codes.

	ZIP Code 78752	ZIP Code 78753	ZIP Code 78758	City of Austin
Race and Ethnicity				
White (%)	27	22	35	48
Hispanic/Latino (%)	50	52	49	33
Black (%)	14	14	8	8
Asian (%)	5	9	6	8
Other Race[a] (%)	4	3	2	3
Income and Poverty				
Median Household Income ($)	51,630	55,132	63,283	78,965
Below Poverty Level (%)	18	17	21	13

[a] American Indian and Alaska Native, Native Hawaiian and Other Pacific Islander, some other race, two or more races. Source: 2017–2021 American Community Survey 5-year estimates.

2.2. *Theoretical approach*

In contrast to deductive reasoning and hypothesis-driven quantitative research, we employed an inductive methodology to understand heat-related health and well-being outcomes, heat vulnerability, and adaptation responses. Briefly, we started with specific data (i.e., qualitative data in response to the questions we asked) and worked up from these data to more general theory. Through this bottom-up process of qualitative data analysis, themes of interest emerged and we sought existing theory to "ground" the emerging themes in. This systematic qualitative research method is known as grounded theory (Charmaz, 2006). Our methodological approach allows for topics such as "health impacts of heat" or "adaptative capacity to heat" to emerge, even though these topics were not explicitly asked about. Following grounded theory, researchers can return to the literature to make sense of the data and build theory.

2.3. *Qualitative interviews*

We conducted one-on-one, in-person, semistructured qualitative interviews at the residences of the 18 study participants or nearby public parks from July–September 2021 during the warm season. A single member of the research team—fluent in both English and Spanish language—conducted all interviews and recorded the interview audio on their password-protected smartphone. Prior to being interviewed, individuals provided their informed consent to participate and be audio recorded, and were reminded that they have the choice to not respond to any interview questions for any reason. Each individual received a gift card valued at $20 for participating. Average interview length was approximately 17 min (minimum = 11, maximum = 29).

We developed a simple qualitative interview script from theory on heat-related health and well-being outcomes, heat vulnerability, and adaptation strategies (Wilhelmi and Hayden, 2010) and our own expertise on climate resilience as local academics, non-profit organizers, and city officials working together since 2019. The script had three main questions and prompts. First, we asked about heat vulnerability: "Imagine it's 105 degrees (Fahrenheit) outside. What does your day look like?" Prompts for this question included "Does that impact you personally?"; "What about your family and friends?"; "At home? At work?"; "When going to work, school, etc.?"; and "On weekends?". Second, we asked about adaptation strategies to heat: "Imagine it's the future and it's 105 degrees (Fahrenheit) outside, what do you see in your community that would make it feel cooler?" Prompts for this question included "What do you see in the street? In the parks?" and "What do you see at home?". The interview closed with an open question: "Is there anything else you would like to share?".

2.4. *Thematic analysis*

Two study researchers worked within NVivo (QSR International, Cambridge, MA, USA) to identify patterns in the interview data using thematic analysis, following guidance by Braun and Clarke (2006). In preparation for analysis, they used Sonix (Sonix, Inc., San Francisco, CA, USA) to transcribe the interview audio to text, per previous studies (Segal et al., 2022; Karidakis et al., 2022), and to translate the 14 transcriptions in Spanish language to English. After familiarizing themselves with the data, they generated codes (i.e., labels that identify a feature of the data of interest), with the minimum unit of analysis defined as a sentence. The coding process relied on the creation of a coding frame to reduce, classify, and synthesize the data systematically (Appendix). Development of the coding frame was based on existing theory on heat-related health and well-being outcomes, heat exposure, sensitivity, adaptive capacity, and adaptation strategies (Adnan et al., 2022; Karanja and Kiage, 2021; Wilhelmi and Hayden, 2010) as well as driven by the data (O'connor and Joffe, 2020).

We arrived at our final coding frame following an iterative process outlined by O'connor and Joffe (2020). First, the researcher most familiar with the subject area, and therefore more qualified to determine the meaningful conceptual breaks in the data according to Campbell et al. (2013), attempted to segment the data and apply relevant codes for a single transcript using the initial coding frame. Second, this researcher created a new document from their coding attempt where the data segments were highlighted but the codes removed; the second researcher then attempted to apply codes to the highlighted segments. Third, the two researchers discussed their independent coding of the same transcript, came to an agreement on any coding discrepancies, and revised the coding frame as needed. Fourth, they applied separate coding for five of the same randomly selected transcripts (28% of the total transcripts) to test for intercoder reliability, which is typically tested on 10–25% of data units (O'connor and Joffe, 2020). The calculated Cohen's kappa statistic of 0.70 equates to "substantial agreement" between coders (Mchugh, 2012). Lastly, the two researchers arrived at the final coding frame by discussing their independent coding of the five transcripts, coming to an agreement on any coding discrepancies, and revising the coding frame as needed. They equally and randomly divided the remaining 12 transcripts to code independently.

After coding, the two researchers sorted the different codes into themes, and collated all the related coded text in transcripts within the themes. Theme development involved a detailed analysis wherein the researchers named each theme, identified the story told by each, and how each related to one another and fit into the broader story of heat-related health and well-being outcomes, heat vulnerability, and adaptation strategies. Our qualitative analysis resulted in six major themes.

2.5. Reflexivity statement

As researchers are the instrument in semistructured qualitative interviews (Pezalla et al., 2012; Wa-Mbaleka, 2019), knowing the individual characteristics of those who directly engaged with the data can provide insight into how their perspectives and assumptions influenced the people and topic being studied. The sole interviewer in this study was a Latina, lower-middle class, cisgender, straight, non-disabled female in her 50's who has lived in South Texas most of her life and in Austin, Texas, since 1997. A high school graduate with an abundance of lived experience in community engagement and grassroots organizing, she is a community health worker trained in diverse community planning for disaster preparedness and recovery. Of the two researchers who processed, analyzed, and interpreted data from interviews, the first was an Asian Latino, upper-middle class, cisgender, straight, non-disabled male in his 30's who has lived in the Southern U.S. his entire life and in Austin since 2019. A faculty member at a university in Austin, he has been formally trained in both environmental health and city & regional planning, with a research focus on urban heat and health. The second staff member who processed, analyzed, and interpreted data from interviews was a white Latina, middle class, cisgender, straight, non-disabled female in her 30's who has lived in the U.S. her entire life and in Austin since 2019. A graduate student training in city & regional planning and public affairs at a university in Austin, she has spent the past decade working on social and environmental policies and city & regional planning. All three researchers have strived for eliminating health inequities facing unfairly marginalized communities. Prior to this study, they had no relationships with study participants.

3. Results

3.1. Heat, health, and well-being

When thinking of days with high temperatures, residents in a low-income community of color in Austin, Texas, mentioned that heat impacted the physical health, mental health, and well-being of household members. Generally, residents shared that heat was uncomfortable and induced fatigue, headaches, nausea, dizziness, and trouble breathing. Most residents found it challenging to describe how heat specifically impacted them, stating it was "unbearable" and "felt sweltering", with several mentioning that they "couldn't stand it". When the interviewer asked one Latina woman what heat felt like to her, she responded, "As sweating, suffocation. It's like something inexplicable. It gives me chills, and at the same time, I feel like vomiting, dizzy. It's a lot of things that I get."

Along with the implications of heat stress on physical health, residents described the pronounced effect of heat on their mental health, partly due to serving as a barrier to engaging in the health behavior of physical activity. One Latina woman explained what heat does to her and her children's mental health, "I get more stressed, more tired. I don't feel like going for a walk to de-stress. We take shelter in the house, hoping the air will keep us cool. It hits us hard because stressed children are locked in." In addition to being a barrier to physical activity participation, residents cited heat as an enabler of sedentary behavior. One Latina woman shared:

"We want to go out, but we do not exercise. We do not walk. We gain weight. We are prone to diabetes. Children no longer want to go out to play… Being locked up because it is very hot, not going anywhere or taking them (her children) to the parks or out in our yard. It affects them to be locked up, and then watching television because they can't go out. They have no choice but to be watching television and playing video games. It affects us because they have to exercise, go out, not just be cooped up."

Lastly, residents revealed that the impact of heat extended beyond the period of heat exposure, later affecting social relationships at home. One Latina woman shared, "Heat affects me too much because my husband comes home tired, not in the mood to play with the girls." Another Latina women mentioned that her son had accompanied her husband at his outdoor construction job and relayed, "I know why dad sometimes comes home in a bad mood. Because he is very tired. It's getting too hot, mom."

3.2. Exposure to heat

Residents experienced high temperatures in outdoor settings, with none mentioning indoor locations as places of heat exposure. Commuting by bus to destinations near one's home, often with other family members, was commonly mentioned as a point of heat exposure. "I was a person who rode the bus for many years battling heat with my girls to the doctor, school, and dentist," described one Latina woman. Another Latina woman shared, "If my children and I go on the bus, we are cool while on the bus, but when we get off and everything, imagine how hot we feel." Residents also noted being exposed to heat when working outside, either in occupational settings or around their residence. For example, a Black woman recollected an intense period of heat exposure while in her yard: "My brother and I were working on a construction project and didn't drink for 30 minutes. I came in and was overheated and screaming for my daughter. I said, come help me and I need water. Almost passed out." Lastly, residents described heat exposure in outdoor spaces intended for recreation. Two Latina women, for instance, shared that heat shortened the amount of time spent at parks and lakes because it was “just not comfortable staying” and that “they can’t stand heat too much”, respectively.

3.3. Sensitivity to heat

Residents stated that the most affected by heat were children and those with pre-existing medical conditions. All but one of the 18 interviewed residents mentioned the impact of heat on children. When asked what her day would look like when 105 °F (41 °C) outside, one Latina women replied, “Difficult, because imagine being outside and sometimes forgetting a bottle of water. You quickly get desperate and the babies. Because imagine, they don’t even talk. One complains, but what about the children?” Another Latina woman described that her autistic son “struggles more to adapt to something”, and that “he doesn’t go outside because it’s hot; he wants to be in the cool.” Several interviewees relayed that heat was challenging for them because of their high blood pressure and living with diabetes. For example, a Latina woman identifying as diabetic stated, “I can’t go outside in the sun, in the heat, because then my blood pressure goes up and I go to the hospital.”

3.4. Adaptive capacity to heat

There were four strategies commonly taken by residents to cope with heat. First, all but one resident mentioned that on days with high temperatures, they would choose to stay home. Residents described staying indoors as “being locked up”, and mentioned the dual threat of heat and the COVID-19 pandemic: “It’s difficult right now… the heat and the pandemic, they have us cornered,” one Latina woman stated. Second, residents shared they drank liquids—generally water—to cope with heat. One Latina woman whose partner worked as a painter told us, “I always try to give him water or lemonade when he comes in because he is very hot all over his body and sometimes all red.” Third, residents stated their household used air conditioning to adjust to heat. For instance, a Latina woman shared what her children say and do upon coming home from school on a hot day: “They can’t stand the heat and say “My God, mommy, it’s so hot“, and then they go sit down and turn on the air.” Lastly, residents said that on days with high temperatures, they would change their schedule to avoid the hottest times of the day. Strategies included not going outside in the middle of the day but rather very early or very late, and minimizing time outside. “If we are outside it is very complicated with the heat. Maybe the longest you can be outside is 10 or 15 minutes, and then it’s back inside again.”, said a Latina woman. In one quote, a Black woman summed up three of the main ways her (and others interviewed) adjusted to heat:

“I’m up every morning around 5:00, and after I finish my coffee, I’m usually outside about 7:30 to 9:30 before the heat comes up. And after the heat comes up, I’m very, very blessed to have air conditioning. I respect the heat and I respect the fact that, if you’re not careful, you could overheat then it’s all medical problems. One of my occupations has been a nurse aid, so I make the point that when it’s that hot not to go outside, I mean, I just don’t play games, it is too dangerous.”

3.5. Barriers to adjusting to heat

Residents revealed three major barriers to adjusting to heat, with the most common being the lack of trees and overall shade in outdoor public spaces for travel, activity, and/or rest. Residents noted the lack of tree-lined streets and its impact on thermal comfort when taking the public bus. One Latina woman who does not own a car relayed that “at some (bus) stops, there is no shade, there are no trees next to them, for one to avoid the heat a little bit.” Further, the lack of shade at bus stops was compounded by characteristics of the bus transit system. Another Latina woman shared, “Sometimes bus stops are very far away and don’t have shade to look forward to. The buses were very late. If you miss one you have to wait for the other, 30 or 40 minutes depending on the route.” Second, residents divulged the lack of greenspace as a barrier to adjusting to heat. There were few parks near them and this affected their health, with a Latino man stating, “I’d like to be able to go outside and kind of walk around. But there are not a lot of green areas around my neighborhood, so I have to stay indoors.” Further, residents noted the lack of shade at parks posed a problem for thermal comfort. While being interviewed at a park near her residence, a Latina woman stated, “here in this part there are a little bit of trees, but imagine, I go to the other side, there is only a little bit, so the sun hits there.” Lastly, residents believed bluespaces were lacking in their community including pools, splash pads, lakes, and rivers. One Latina woman said, “you can’t go to the river because all the people settle there. We don’t even have a pool where we can go, or parks that have a splash pad or something where the kids can play.”

Along with these three barriers, residents shared two potential future barriers to adjusting to heat. One was the cost of electricity. A Black woman said to the interviewer, “I used to pay about $40 for electricity in Austin… so when I saw $80, $90, it was so strange and when I saw $140, I wasn’t used to that.” The second was the threat of power outages. Another Black woman had referenced Winter Storm Uri—a severe weather event occurring in February 2021, six months prior to her interview date—in what could happen to electrical power on days with high temperatures: “Right now we have a certain amount of technology and things that are under control, but then what if we have a problem with shutdowns like we had at the winter thing that went on this last year?”

3.6. Recommended adaptation strategies to heat

When asked what they would like to see in their community to make it feel cooler on days with high temperatures, residents provided five major adaptation strategies. First, planting trees was mentioned by all residents but one, who stated, “I cannot even imagine a solution for the heat. I don’t know… It seems like nobody’s smart enough to know exactly what to do.” Conversely, other interview respondents recommended planting trees because “it is the only thing we can do” and that “nothing else can help us more than nature”. Residents wanted tree-lined streets so their family could “relax and breathe a little fresh air”, as well as to offer “more shade at the bus stops". Residents championed for trees planted at parks and areas intended for physical activity. For instance, one Latina woman offered a recommendation for safe play in the heat:

"There should be more trees, safe playgrounds for the children, where they also have trees nearby to have shade where they are playing, because sometimes the playgrounds are very nice and everything, but no, sometimes the sun hits them directly. It would be good if we could think of putting playgrounds and trees around where it covers the children's space so that they can run around cooler, feel less hot."

As a second adaptation strategy, residents recommended installing artificial shade structures for thermal comfort. Suggested installation sites for these structures included along the street or in parks, with one Latina woman stating the structure could be made of solar panels "that can give a shaded area, and at night can put light in the street or in the park". Third, residents advocated for additional greenspace (i.e., parks) as an adaptation strategy. For instance, a Latina woman wanted "a little park in the apartments because most children here spend time locked up (indoors)". Fourth, residents recommended more bluespace for heat adaptation. Interviewees wanted pools at their residence so they could "go for a swim when it gets too hot". In public settings, they wanted splash pads and other water features "for children to play and all that." Lastly, residents recommended installing more public drinking fountains in their community to replace lost fluids in the heat. One Latina woman said, "maybe some water fountains for the people who are walking, right? Or even for animals… they sometimes put the fountains for people and dogs."

4. Discussion

From conducting qualitative interviews with 18 residents, all of whom were economically disadvantaged and most of whom identified as female ($n = 17$) and Latino ($n = 16$), in Austin, Texas, we gained insight into their heat-related health and well-being outcomes, vulnerability to heat, and recommended adaptation strategies. Our thematic analysis identified six themes: 1) heat impacted the physical health, mental health, physical activity, and social relationships of household members; 2) heat exposure was highest during active transportation, outdoor work, and recreation; 3) children and those with pre-existing medical conditions were perceived as most sensitive to heat; 4) residents coped with heat by staying at home, drinking liquids, changing their daily schedules, and using air conditioning; 5) barriers to adjusting to heat comprised the lack of trees/shade, greenspace, and bluespace as well as potential future barriers of electricity cost and power outages; and 6) residents recommended planting trees, installing artificial shade structures, adding greenspace (i.e., parks), adding bluespace (i.e., pools, splash pads), and installing more public drinking fountains in their community.

Our results corroborated those from other qualitative studies on heat vulnerability, albeit in different settings and populations. Previous studies shared our finding that heat induced tiredness, headaches, malaise, and dizziness (Banwell et al., 2012; Guardaro et al., 2022; Mathee et al., 2010; Pasquini et al., 2020) along with psychological impacts (Mathee et al., 2010). Studies have focused on populations considered sensitive to heat such as older adults (Abrahamson et al., 2009; Banwell et al., 2012; Eady et al., 2020; Hansen et al., 2011; Jonsson and Lundgren, 2015) and outdoor workers (Mathee et al., 2010), with participants in two studies perceiving those with high blood pressure to be at higher risk of health issues from heat (Mathee et al., 2010, Pasquini et al., 2020), as in our study. Other studies also found that individuals coped with heat by choosing to stay home, drinking liquids, using air conditioning, and changing their schedule (Abrahamson et al., 2009; Guardaro et al., 2022; Banwell et al., 2012). Same as our study participants, residents in Phoenix, Arizona, felt "locked in" (Guardaro et al., 2022) and those in Sydney, Australia, felt "couped up" (Banwell et al., 2012) when choosing to stay home to adjust to the heat. Guardaro et al. (2022) shared our finding that residents viewed the lack of trees, shade, and bluespaces as barriers to adjusting to heat. Residents in our study had suggested planting trees and adding greenspace and bluespace as adaptation strategies to heat, the same recommendations given by operational staff and older residents in a large Swedish municipality (Jonsson and Lundgren, 2015).

We have identified several unique contributions of this work, the only to use a qualitative approach to learn how residents in a low-income community of color with high urban heat island intensity perceive heat in relation to health, well-being, vulnerability, and adaptation strategies. Results showed that residents saw heat as a barrier to them and their children engaging in physical activity, and that this lack of physical activity affected their mental health. For outdoor workers, the physical and mental toll of heat while on the job negatively affected their social relationships later at home. Residents emphasized their concern for children on hot days, and often centered their recommended adaptation strategies around promoting safe physical activity of children such as installing splash pads and planting trees and installing shade structures at playgrounds. Taking the bus was a point of exposure with social equity concerns. Residents of Austin who commute by public transit have the lowest median earnings of all workers (U.S. Census Bureau, 2019a), and more than a quarter of these individuals do not have access to a vehicle (U.S. Census Bureau, 2019b). These individuals may have no choice but to travel by bus, which most often requires walking outside. As such, interviewed residents advocated for tree shade along streets and at bus stops.

While quantitative data from the Urban Heat Watch program revealed that air temperatures in study ZIP Codes were higher than surrounding areas (Fig. 1), participants in our study did not reference that their community was warmer than others nearby (i.e., urban heat island effect). Further, no residents mentioned indoor heat exposure as a concern, which may be related to the high prevalence of air conditioning use in the region: an estimated 94% of households in the Austin-Round Rock metropolitan statistical area had central air conditioning in 2013 (U.S. Census Bureau, n.d.-b). Residents in Phoenix, Arizona, another city with a warm climate, shared this reliance on air conditioning (Larsen et al., 2022). However, those we interviewed expressed concern about electricity cost and power outages, which could threaten their most cited coping strategy: staying home. The concurrence of a blackout during extreme heat conditions is a valid concern: one study estimated that a multiday blackout event during a heat wave would more than double the rate of heat-related mortality across Atlanta, Georgia; Detroit, Michigan; and Phoenix, Arizona, with half of the population of Phoenix estimated to need emergency care for heat-related conditions (Stone Jr. et al., 2019). One coping strategy for heat that residents in our study did not reference was social support, a factor that had contributed to the relatively low Latino mortality rate during a deadly heat wave in Chicago, Illinois, in 1995 (Klinenberg, 1999). These contrary findings may be related to our interview questions focused on singular days with high temperatures, which may not be perceived as dangerous as a multiday heat event that requires assistance from others.

Nearly all residents voiced their desire for more trees in response to heat. The almost universal interest in tree planting may be due to a combination of factors, including personal experience using tree shade to cope with heat, the relatively high prevalence of tree canopy compared to other adaptation strategies outdoors (e.g., artificial shade structures), and local advocacy efforts supporting the urban forest. Typically, U.S. communities consider five main strategies to reduce urban heat islands: 1) increasing tree and vegetative cover, 2) installing green roofs, 3) installing reflective roofs, 4) installing reflective or permeable pavements, and 5) utilizing smart growth practices—a range of strategies that make communities more livable and protect the natural environment (U.S. Environmental Protection Agency, 2022b). Residents in our study mentioned increasing tree and vegetative cover yet none of the other main adaptation strategies. Further, residents recommended installing artificial shade structures and adding bluespace, both of which have been shown to moderate temperatures (Gunawardena et al., 2017; Lanza et al., 2021), as well as installing public drinking fountains. Residents did not mention that community resources to adjust to heat were unfairly distributed, even though research has shown that tree canopy cover is generally lower in low-income communities of color than affluent, predominantly White communities in Austin and other U.S. cities (Lanza et al., 2019).

This study supports the need for municipalities, when developing plans to manage heat, to collaborate with community members in designing strategies to reduce their vulnerability and promote positive health and well-being outcomes. While most large cities in the U.S. mention urban heat in their climate plans as an environmental problem to address, few frame the problem with any level of specificity (Turner et al., 2022). Community members can bring this needed specificity as experts in how they and their community function, knowledge that cannot be readily replicated by other individuals or approaches. With heat governance in its nascency, city officials should consider direct involvement of community members throughout the planning process—alongside key collaborators from academic institutions, non-profit organizations, and health departments—to design equitable, heat-resilient cities.

We believe study findings are applicable to other low-income communities and communities of color in the U.S. that are located in warm climates. Among population subgroups, our results may be most relevant to Latina women with children, which constituted 78% of our study participants. Two limitations of this work may impact the generalizability of results. First, our use of snowball sampling to recruit a convenience sample of study participants led to a final sample in which individuals may be similar to one another and therefore have similar responses to interview questions, which may not be representative of responses from their community at large or other communities. In addition, results may have been more generalizable if we had used standard interview questions, which have yet to be developed.

5. Conclusions

In this study, we conducted qualitative interviews with residents in a low-income community of color with high urban heat island intensity to better understand how they perceived heat in their community. From a thematic analysis based on existing theory, we revealed residents' perceptions on the impacts of heat on health and well-being, settings of high heat exposure, sensitive population groups, adaptive capacity, barriers to adjusting to heat, and adaptation strategies. With community voice as our data, we identified gaps unfilled by quantitative assessments of heat-related health and well-being outcomes, heat vulnerability, and adaptation strategies. Contextualized and qualitative assessments of vulnerability have been undervalued, yet the resulting rich, thick description can complement quantitative data to develop policies and interventions that support health and well-being on days with high temperatures. Requiring meaningful community involvement throughout climate resilience efforts has the potential to result in adaptation strategies that are truly for the community.

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CRediT authorship contribution statement

Kevin Lanza: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Visualization, Project administration. **Jessica Jones:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – review & editing. **Frances Acuña:** Investigation, Resources, Writing – review & editing. **Marc Coudert:** Writing – review & editing. **R. Patrick Bixler:** Writing – review & editing. **Harsh Kamath:** Writing – review & editing. **Dev Niyogi:** Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix

Coding Frame

1. Sociodemographic Information of Study Participant

A. Age
B. Have Children
C. Type of Residence (e.g., apartment, house)
D. Years at Residence
E. Country of Origin
F. Year in U.S.
G. Car Ownership
H. Other

2. Heat Exposure

A. Occupational Exposure
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
B. Household Exposure
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
C. Travel-Related Exposure (e.g., to/from school, work, stores)
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
D. Exercise/Recreation/Play/Sport-Related Exposure
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
E. Other

3. Sensitivities to Heat

A. Age
  a. Young Household Members
  b. Elderly Household Members
B. Diabetes
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
C. Overweight or Obese
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
D. Cardiovascular/Heart Disease
  a. Resident
  b. Spouse/Partner

    c. Children
    d. Other Person
  E. Pregnant
    a. Resident
    b. Spouse/Partner
    c. Children
    d. Other Person
  F. Disability
    a. Resident
    b. Spouse/Partner
    c. Children
    d. Other Person
  G. Prescription Drugs/Medications
    a. Resident
    b. Spouse/Partner
    c. Children
    d. Other Person
  H. Other

4. Impact of Heat on Physical Health

A. Exhaustion, Tired, Low Energy
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
B. Uncomfortable/Can't Stand It/Too Much
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
C. Nauseous, Feeling Sick, Vomiting, Faint/Fainting
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
D. Other

5. Impact of Heat on Mental Health

A. Mood (e.g., happy, angry)
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
B. Stress
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
C. Worry/Fear/Anxiety
  a. Resident
  b. Spouse/Partner
  c. Children
  d. Other Person
D. Other

6. Adaptive Capacity to Heat

  A. Use Air Conditioning
  B. Seek Help from Others

C. Sit/Rest/Be Sedentary/Less Physical Activity
D. Minimize Heat Exposure (e.g., don't go/spend less time outside, change schedule)
E. Open Windows
F. Use Fans
G. Go under Artificial Shade Structures
H. Go Under Tree Shade
I. Go to Park
J. Go in Water Body (e.g., shower/bath, pools, lakes, rivers, splash pads)
K. Drink Liquid/Use Ice
L. Go to Public Cooling Center
M. Other

7. Current Barriers to Coping with Heat (in home or urban environment)

A. No Air Conditioning/Poor Quality Air Conditioning
B. Social Isolation/Lack of Help from Others
C. Lack of/Poor Quality Windows
D. Lack of Fans
E. Lack of Artificial Shade Structures
F. Lack of Tree Shade
G. Lack of Parks
H. Lack of Water Bodies (e.g., pools, lakes, rivers, splash pads)
I. Lack of Water Fountains
J. Lack of Public Cooling Centers
K. Financial Costs/Bills
L. Problems with Housing Structure (e.g., walls, insulation, ventilation)
M. Other

8. Adaptation Strategies for Heat Recommended by Study Participants

A. Air Conditioning
B. Social Community/Help from Others
C. Windows
D. Fans
E. Artificial Shade Structures
F. Trees
G. Parks
H. Water Bodies (e.g., pools, lakes, rivers, splash pads)
I. Water Fountains
J. Public Cooling Centers
K. Financial Assistance
L. Improved Housing Structure (e.g., walls, insulation, ventilation)
M. Other

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