SPECIAL COLLECTION: ALTERNATIVES TO AIR CONDITIONING: POLICIES, DESIGN, TECHNOLOGIES, BEHAVIOURS

RESEARCH

Living with air-conditioning: experiences in Dubai, Chongqing and London

NIAMH MURTAGH
SULAFA BADI
YALING SHI
SHEN WEI
WEI YU

*Author affiliations can be found in the back matter of this article

ABSTRACT

Extreme heat is a likely consequence of global warming, leading to increased mortality and reduced wellbeing. There is limited research evidence of experiences of living with and without air-conditioning (AC), commonly regarded as the sole technological solution, but such knowledge is essential to progressing alternative approaches. A total of 72 participants were interviewed in an exploratory cross-cultural phenomenological study in Dubai (United Arab Emirates—UAE), Chongqing (China) and London (UK). In Dubai and Chongqing, AC was ubiquitous and central to life in the hotter months, although not for all socio-economic groups. AC enabled indoor work to proceed, but a restricted indoor life meant less exercise, less social interaction and health issues. Participants had over-adapted, not to heat but to cold indoor temperatures, which were uncomfortable for many. In London, AC was not yet used, but the purchase of AC was being contemplated. The London participants showed a range of behavioural adaptations to heat. To reduce dependence on AC, regulations and behaviour change interventions regarding AC settings should focus on acclimatisation to heat. Changes in societal patterns, such as workhours, and behavioural adaptations, such as informed use of shading, can help mitigate heat. Deconstruction of the meanings of AC-related thermal comfort is needed to incorporate physiological, behavioural and social responses.

POLICY RELEVANCE

The study findings show the following: AC technology is already culturally embedded in societies in hot climates, but is not yet seen as a necessity in temperate climates, offering a window of opportunity. This window could close rapidly, so initiatives are needed now to encourage householders to improve heat protection around their homes.

CORRESPONDING AUTHOR:
Niamh Murtagh
The Bartlett School of Sustainable Construction, University College London, London, UK
n.murtagh@ucl.ac.uk

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In hot climates, while AC enables life to continue, it is not a panacea. AC does not provide thermal comfort universally: people do not experience AC as providing a comfortable environment. Better regulation of building and urban design is needed to ensure climate and context appropriateness. Behaviour change interventions to reduce the overuse of AC are recommended to focus on health as well as energy. Existing discourses on AC as the unique and adequate solution to future heat must be challenged in order to open up the discussion to include behavioural, social, built environment and other technological solutions.

1. INTRODUCTION

The extreme heatwaves in Northwest America and Southeast Europe during summer 2021 were powerful symbols of warming planetary weather systems. The most recent report from the United Nations' (UN) Intergovernmental Panel on Climate Change (IPCC) estimated that extreme heat events over land, which would have occurred once in 10 years without human influence on the climate, will become four to nine times more frequent, and 1.9–5.1°C hotter this century (IPCC 2021). From 2020 to 2021, an additional 50 million people were classified as being at high risk from lack of access to cooling (SEforALL 2021). An estimated 30% of the global population already experiences life-threatening temperatures for at least 20 days a year, and this is predicted to increase. The UN has called for countries to develop national cooling action plans (NCAPs) which identify vulnerable groups, legislate for energy performance standards and support renewable energy for cooling (Cool Coalition 2022).

Humans have evolved to live in a relatively narrow band of temperature (Xu *et al.* 2020a). The societal toll of heatwaves can be accounted in part through measures of excess mortality. Anthropogenic climate change was estimated to have increased the risk of heat-related mortality during the 2003 heatwave by 70% in Paris and 20% in London (Mitchell *et al.* 2016). Modelling based on climate prediction scenarios have shown increasing heat-related mortality as greenhouse gas emissions grow, with warmer and poorer countries disproportionately affected (Gasparrini *et al.* 2015). Recent work has additionally demonstrated rates of premature death attributable to higher temperatures (Arbuthnott *et al.* 2020). In addition, a recent study has proposed that as the planet warms, within 50 years up to one-third of the world's population will live in regions with mean average temperatures outside the range which prevailed throughout human history (Xu *et al.* 2020a). Severe heat impacts productivity at work, individual wellbeing and quality of life (Kjellstrom 2009; Macpherson & Akpinar-Elci 2015; Zander & Mathew 2019). The more frequent and more intense heatwaves predicted in IPCC reports will have a significant impact on human societies above and beyond health risks.

Introduced in the early 20th century, air-conditioning (AC) systems were initially designed to change temperature and humidity to allow easier handling of materials and processes in printing and then manufacturing. In-depth socio-historical accounts of AC in the US (Cooper 1998; Ackermann 2010) mapped how AC technology began to permeate cinemas and department stores in the 1920s, before surging in the residential market from the 1950s. Amongst the insights they offer are the importance of controlling the climatic environment as an objective of the technology, and the role of marketing in the creation of demand for cooling. Ackermann (2010) connected discourses around AC to ideological stances with racial and colonialist overtones, and in which extreme heat was related to backward and unprogressive conditions in contrast to vigorous, modern, superior Western societies. The association between AC, luxury and aspirational lifestyles has continued to be documented, alongside acknowledgement that AC has become increasingly accessible globally (Basile 2014; Shove *et al.* 2014). Insights from a social practice theory perspective have pointed to the socially constructed nature of cooling demand (Walker *et al.* 2014). Marketing campaigns in the mid-20th-century US positioned coolness and comfort as a requirement for everyday life; AC as modern and healthy; and both comfort and AC as essential for 'health and efficiency [...] progress and civilization' (Ackermann 2010: 17).

Social practice theory describes how meanings, knowledge and materiality, including technology and buildings, co-evolve (Shove *et al.* 2014), and provides valuable insights into societal patterns such as technology diffusion, but there is also a need to understand individual behaviour and experience. Despite near saturation of the US residential market in AC (Basile 2014), 29% of a sample of 719 adults in New York chose not to use it during hot weather (Lane *et al.* 2014), and households with AC in Arizona showed high variability within and between households in terms of usage (Wright *et al.* 2020). Alternative means of protection exist, other than simply switching on the AC. The design of the built environment matters for protecting people from extreme heat (IPCC 2014). Recommendations for design and retrofit for adaptation to heat include exposed thermal mass and night ventilation, reducing glazing on south-facing facades and external shading, especially from trees (Pelsmakers 2015; Porritt *et al.* 2012). In urban outdoor spaces, changing urban geometry, increasing vegetation, cool surfaces and bodies of water can contribute to reducing ambient temperatures (Lai *et al.* 2019).

Individual behaviours also provide protection, but it is striking that the UN's framework for NCAPs (Cool Coalition 2022) omits reference to behaviour. While cooling has been, and continues to be, extensively studied, particularly from an efficiency perspective, fewer studies have examined occupant behaviour (O'Brien *et al.* 2020). Research that has included behaviour has tended to focus on older people as a vulnerable cohort. In a qualitative study with people aged over 65 years in Australia, participants reported less activity, eating lighter foods and increasing fluid intake, more showering or washing, and the altered use of windows and curtains, in addition to extensive use of AC. They recalled pre-AC behaviours of sucking ice and putting wet cloths in front of fans (Hansen *et al.* 2008). While a more recent survey of 1000 older people in Canada collected data on behaviours, the behaviours were somewhat arbitrary (going swimming, using the stove) and did not include use of AC or fans, ventilation or night-time strategies (Valois *et al.* 2020). A more systematic approach to evaluate future dependence on AC modelled three groups of adaptations in Paris: green infrastructure, physical infrastructure and behaviour, at city, local and individual levels. A combination of all actions could reduce energy demand by 60%, leading to the conclusion that AC will remain a necessary and widespread fixture in the future, even in temperate climatic zones (Viguié *et al.* 2020). Although Viguié *et al.* (2020) included individual behaviour in their modelling, this was limited to setting the AC to 26–28°C compared with 23°C.

In Japan, a survey of mainly older people found evidence for changes to fluid intake, use of AC especially at night and staying indoors as behavioural responses to heat (Kondo *et al.* 2021).

An earlier UK study compared behavioural impact with building design or retrofit changes to assess effectiveness in protecting a home and a school against overheating (Coley *et al.* 2012). Interestingly, one behaviour modelled was starting the school day two hours earlier—a social routine change—but overall, the behaviours considered were very limited and mainly comprised window opening. Although this study concluded that behavioural change can be as effective as structural changes in reducing overheating, the assertion was overly general, given the possible types of building adaptation, the spectrum of building uses and occupants, and the wide range of behaviours that can be considered.

A qualitative study with Qatari residents that focused on AC usage demonstrated social dependence on AC alongside acknowledgement of uncomfortably low temperatures and negative impact on social interactions (Hitchings 2020, 2022).

In a Chinese context, recent studies on occupants' use of ACs adopted quantitative methods, such as using smart energy sockets (Liu *et al.* 2021) and mixed-method using sensors and smartphone questionnaires to determine AC usage (Song *et al.* 2018).

The International Energy Agency (IEA) Annex 66 initiative (2014–16) acknowledged the need for further collaborative work on occupant behaviour in buildings (IEA-EBC 2016), and an increasing focus on behaviour can be noted in research bearing on AC usage. However, the mix of methods indicated above, while valuable, may be critiqued on the relative paucity of in-depth qualitative

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studies. Quantitative studies unavoidably measure what is known already: qualitative studies are a necessary complement to break new ground, to provide insights into people's experience and to consider context.

The current study extends the existing research by collecting contextualised data on everyday heat-related experiences and behaviours with working-age adults in a variety of climatic settings, posing the research question: How is everyday life lived in conditions of extreme heat and, in particular, what role does AC play? Understanding experience and behaviour is a prerequisite to developing alternatives to AC. Three cities from different climatic regions, as classified in the Köppen–Geiger climate classification system (Beck *et al.* 2018), were selected for data collection: Dubai in the United Arab Emirates (UAE), a dry, hot desert region; Chongqing, China, in a humid, subtropical region; and London, UK, in a temperate, marine west coast region. The three study sites offer the potential to learn from different climatic settings, from cities which have always dealt with extreme heat to a temperate-zone city that is beginning to deal with more frequent and intense heatwaves. The study makes a novel contribution in providing a phenomenological investigation and cross-cultural comparison of living with, and without, AC during extreme heat.

2. METHODS

A brief outline of the study cities is now presented:

- *Dubai* is situated on the Gulf of Arabia (Persian Gulf). It is the largest city in the UAE with a population of 3.4 million. The city has developed rapidly from a population of 183,000 in 1975; and 92% of residents were not born in the UAE (DSC 2020). The Dubai region has a subtropical desert climate, with hot and humid summers and warm winters. Air temperature ranges up to 48°C in the hot season, which lasts from mid-May to late September, with average daily temperatures over 37°C (Mohammed *et al.* 2020). AC is 'ubiquitous' (Stroeve *et al.* 2016) and estimated to consume 79% of annual electricity consumption for a typical villa in the region (Dubey & Krarti 2017).
- *Chongqing City* lies centrally in China, in a mountainous region at the confluence of the Yangtze and Jialing rivers, with a population of almost 9 million. Humidity is high, above 75% all year, with fog for over 100 days per annum. Average temperatures are around 33°C in July and August, but maximum temperatures range from 38 to 41°C between May and September (Chongqing Meteorological Bureau 2020). A small-scale study by one of the authors (W.Y.; unpublished) found that AC usage accounted for 47% of total energy consumption in summer.
- *London*, in the south of the UK, has a cool temperate climate. The hottest months are July and August, with mean daily maximum temperatures of 23.5°C. Heatwaves lasting several days are increasingly common, and the highest recorded temperature was 37°C in 2003 (Met Office 2016). The population of London is approximately 9 million, and 63% were born in the UK. Very few UK homes have AC, estimated at 0.5% in 2008 (DGN 2021).

A phenomenological methodology was appropriate to address the research question. Semi-structured interviews were chosen to enable a deep and rich exploration of behaviours, recognising that each person is a unique nexus of physiology, context, social demands and cultural learning through their lifespan and experience. While each individual brings a unique background to their experience, their behaviours are likely to follow accepted social routines and the beliefs they express can reveal underlying cultural norms. As an inductive and exploratory qualitative study, no theoretical framework was identified a priori (Hitchings 2020).

Because heat is particularly problematic in cities (Hoag 2015), participants living in urban or suburban settings were recruited. Due to additional risks from hot weather for older people and those with underlying health conditions (PHE 2018), which may lead to systematically different experience and behaviour, participants were selected to be working-age adults (20–65 years old) with no known heat vulnerability. In each city, the researchers aimed to recruit to a quota that was balanced across gender and the age range (*i.e.* two women and two men in the 20s, 30s, 40s, 50s and 60–65 age bands) from within social and work networks of the researchers and through snowballing. There were no other inclusion requirements. Access to or use of AC was not a precondition: this was revealed by participants in their accounts of dealing with extreme heat.

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A semi-structured interview schedule was prepared with questions on socio-demographics, how participants coped with hot weather, what appliances they used at home to deal with heat, how they ventilated their home, and what would help them to deal better with heat in the future. With minor changes for location, the same schedule was used for all participants. Interviews were conducted in English in Dubai and London, and in Chinese in Chongqing. Interviews were online, audio recorded with permission and transcribed verbatim, and the interviews in Chinese were translated. The interviews were conducted by researchers resident in each location, in August and September 2020, during the hottest months in Dubai and Chongqing, and during and within two weeks after heatwave conditions in London.

Table 1 summarises the participants' characteristics. Participants were asked their type of work: in Dubai, the most common professions were administration, marketing and sales, and included a commercial airline pilot, a freelance researcher, a medical technologist and a performance development coach. In Chongqing, the majority of participants were postgraduate students and also included participants in marketing, urban design, construction and a full-time homemaker. In London, the most common profession was administration, and participants included a nurse, a plumber, a cake-shop owner and a social worker.

Table 1: Participant socio-demographics.

	DUBAI	CHONGQING	LONDON	TOTAL
Total participants	26	22	24	72
Female	13	4	14	31
Male	13	18	10	41
Age (years)				
20s	4	8	5	17
30s	11	9	6	26
40s	8	2	5	15
50s	3	2	6	11
60s	0	1	2	3
Grew up in the UAE/China/UK	2	22	19	43
Work				
Paid employment	23	17	22	62
Student	2	4	2	8
Other/unknown	1	1	0	2
Home				
Flat	20	19	6	45
House	6	2	18	26
Dormitory	0	1		1

Thematic analysis was conducted on the data (Braun *et al.* 2019). For qualitative research, standards of trustworthiness, comprising fidelity and utility, are more appropriate than concepts of validity and statistical generalisability applicable for many quantitative methods. Fidelity to the subject matter entails aiming to capture lived experience through rich description, based on adequate data. Utility includes contextualisation and contribution of meaning (Levitt *et al.* 2017). The next section aims to present rich description, context and meaning.

The presentation of the findings below is structured first by city, in the order Dubai, Chongqing and London, and then under themes relevant to AC: usage in everyday life; impact on lifestyle, work and health; and equality of access. A final theme relates to the participants' suggestions on how heat could be better dealt with in the future, compared across the three cities. To protect anonymity, quotations are identified by a code that indicates the city (D, C or L), the participant's number and the participant's gender (F, M), *e.g.* D-15F was female, participant number 15, in Dubai.

3. FINDINGS

3.1 DUBAI

3.1.1 Dubai: AC usage in everyday life

The Dubai participants described the ubiquity of AC in homes, offices, cars, shopping malls and other leisure locations. Many had central AC at home, while others referred to room units:

> I have AC everywhere at home, in the bedroom, in the sitting room, in the kitchen and the toilets, everywhere.
>
> (D-15F)

Typically, AC systems were switched on continuously throughout the summer. Participants referred variously to a period of three to nine months with May/June–October being common. Most ran their systems 24 hours a day in this season. A few switched it off intermittently, or in the evening or when leaving the home, but this was uncommon. The AC system was used for ventilation as well as cooling. At least one participant never opened their windows at home. Most participants limited opening windows to very short periods of time (*e.g.* 15 minutes) or to the winter season.

While one participant set her system to 26°C and another participant:

> use[d] it at minimum 24[°C] in the day, not less […] we're a very sustainable family
>
> (D-12F)

other settings were lower and temperatures of 21, 20 and 18°C were mentioned. Some described temperatures they experienced as very cold, both at home and in the office:

> sitting at home and the AC is always in a full blast really, so sometimes it's freezing. So, you know, at night especially, it's really, really cold in my house,
>
> (D-20F)

Although it could be expected that individuals could choose their preferred temperature in the home, in some cases this was negotiated with family members, even young children. Disagreement over comfortable temperatures played out in the work environment too:

> Many of [the people] here like nationals […] are getting used to […] very low AC conditions. Myself, I'm not adapting to that […] I have a winter jacket in my workplace actually. […] Winter jackets like those you are wearing in some icy areas. I need to warm myself up from the low AC.
>
> (D-26F)

In this quotation, the participant attributed a desire for very low temperatures to people who may have been born in the UAE. She herself had not acclimatised to cold indoor temperatures and found such conditions uncomfortable, wearing not simply additional clothing but heavy winter clothing to compensate.

The participants in Dubai readily accepted their dependence on AC: 'You cannot live without it' (D-11M), and noted that the pervasiveness of the technology meant that they could be unaware of the outside temperature or season. Only one participant described an occasion when the AC failed: there was an assumption of uninterrupted access to cooling systems.

Few references were made to the design or construction of the home. Two participants mentioned that ceramic or marble flooring was the norm, and possibly required by regulations, as carpets would mean hotter rooms. Floor-to-ceiling glazing was referred to by others—curtains were used to protect against direct sunlight, but no mention was made of external shading. With the exception of the reference above to being a 'sustainable family', very few participants made a connection between AC use and environmental impact.

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3.1.2 Dubai: impact of AC on lifestyle

Ubiquitous AC facilitated a particular lifestyle in Dubai. For up to six months a year participants stayed indoors. The heat meant:

> everything—lifestyle, totally different, completely different lifestyle from the scratch of what you eat, the way of how you sleep, the way how you dress and many other things.
>
> (D-17M)

Life was arranged around the seasonal and diurnal patterns of heat: 'you accommodate and rearrange the agenda' (D-26F). The indoor lifestyle meant that visiting the beach was not possible, except perhaps at sunrise or sunset. Any outdoor exercise, even going for a walk, was too uncomfortable to consider. For many of the participants, this meant much less exercise. Some enjoyed using air-conditioned gyms and swimming pools, but several talked of missing the opportunity to walk, to go to different places, to experience nature or the desert.

The places that people could visit were commercial: malls, hotels, restaurants, cinemas, gyms and swimming pools. For some, there was a sense of imprisonment:

> what we do every year, we lock ourselves at home and when we go out, we go to cinemas, to malls, to closed areas.
>
> (D-10M)

Another described it as 'a feeling of a lockdown even before corona[virus]' (D-12F). Even though some activities were possible within these closed areas, the experience was not the same:

> Many activities that you need to do it outside you can't [...] bicycling, for example, like jogging, these type of things. [...] And the feeling of doing these things in closed area is different than the feeling when you're doing in open area [...] because outside is one open area, you will feel like more freedom [...] and you'll enjoy it more.
>
> (D-16F)

The heat also had potentially negative consequences on social relationships. Although the air-conditioned commercial venues offered possibilities for activity, one participant noted that the heat limited joint family activities, and several participants spoke of reduced socialising which affected their social relationships:

> Even I stopped my social responsibility, visiting relatives or family or friends, I stopped that during hot weather.
>
> (D-27M)

The participants spoke of meeting friends and family at air-conditioned restaurants, for example, but there was a pattern, particularly among the male participants, of references to adverse impacts on their social relations caused by the heat and not alleviated by AC.

Overall, the responses contrasted winter-time activities such as barbeques, sports, visiting different places and outdoor socialising with the limited, indoor existence during the hotter months. Most of the participants arranged their holidays to travel away from Dubai for up to six weeks during this time, spending time in Europe or Asia or returning to family in countries such as Jordan, Lebanon or Tunisia where they found it more comfortable, where 'it's normal hot' (D-16F). Some travelled in-country at weekends to cooler locations such as Fujairah on the eastern seaboard of the UAE.

3.1.3 Dubai: impact of AC on work

In terms of working life, some adjustments for heat were mentioned. A few participants referred to stoppage of outside work, particularly on construction sites, between 12:30 and 15:30 hours on hot days. One participant spoke about health and safety responsibilities on construction sites as including provision of cold water for workers and advising on hydration. Others limited some activities in the hottest weather by staying in the office rather than visiting customer sites or completing deliveries early in the day. Although a few participants felt that the heat impacted their productivity at work, most felt that AC in offices meant there was little negative effect on their productivity. Thus, AC meant that working life for indoor workers was mostly unaffected by the climate.

3.1.4 Dubai: impact of AC on health

However, the prevalence of AC was not without problems, and health issues were mentioned by many participants. A few felt that living with continuous AC was probably detrimental to their health, and others cited specific ailments. These included neck pain, stiff muscles and back pain; nosebleeds when the temperature was too low overnight; and more allergies:

> we are much more prone to have asthma or maybe allergies [...] because the dust is all circulating inside the house.
>
> (D-18F)

The lack of fresh air was an issue for some. For several, moving between extreme temperatures was a significant health concern. The very low temperatures of AC, in the office and from centralised systems in apartment blocks, were experienced as uncomfortable:

> So for me, still I am freezing, even in the summers, I mean inside the offices and [elsewhere].
>
> (D-12F)

Low levels of vitamin D were mentioned as a result of the indoors lifestyle that minimised exposure to sunlight.

3.1.5 Dubai: implications for equality

In the responses, references were made to more vulnerable groups. Children were seen to be potentially more at risk from the heat if allowed to play outside, or limited in only having indoor activities. Few participants mentioned the cost of AC. One participant who had grown up in the Philippines admitted:

> To be frank and honest, in the flat, it's not only us [participant and her husband] living there [...] here, especially Filipinos have a lot of people around them living with them.
>
> (D-2F)

As a result, she had access only to one room and no control over the temperature. Notably, this participant was the only interviewee to mention AC outages, and the challenges she faced using public transport for commuting, offering a glimpse into different experiences of different socio-economic groups.

3.2 CHONGQING

3.2.1 Chongqing: AC usage in everyday life

In Chongqing, all participants spoke of their use of AC, either central AC or units in different rooms. Some used electric fans in addition to AC, or in place of, on occasion. Most participants kept the AC running all the time when they were home, including all night. One said:

> The hotter it is outside, the lower temperature I will set on the air-conditioner. Sometimes I wear a long-sleeved blouse and a pair of trousers, then go to bed with thick cover.
>
> (C-10F)

However, not everyone used AC continuously: 'When I can't stand it, I turn on the air conditioner' (C-18M). At night-time, several participants found continuous AC too cold and set it to go off after a few hours. Most, though not all, kept the windows closed when the AC was running, and opened windows for ventilation only when the temperature outside cooled down.

The participants spoke of AC as ubiquitous, as essential to cope with hot weather and as an accepted social norm. They readily expressed dependence on AC: 'I can't live without the air conditioner' (C-19M), and it provided reassurance that they could cope with the heat provided they had AC. One articulated this development of dependence:

> Now our life has improved. We can turn on the air conditioner when it gets hot or cold. Slowly, people can't do without it.
>
> (C-6M)

3.2.2 Chongqing: impact of AC on lifestyle

During the summer months in Chongqing, the most common adjustment was to stay indoors. This meant taking less exercise, fewer walks and little or no aerobic exertion, although some participants increased how often they swam. Some tried to take exercise in the evening and, in general, people reported more evening activities but less activity overall. In particular, socialising was reduced:

> I would not even want to go out, reduce socialising, reduce outdoor activities, maybe it is not healthy, it will be bad both mentally and physically.
>
> (C-8F)

The participants used online communications more and ordered more takeaway meals. If they were going out, they chose air-conditioned transport such as taxis and metro.

Staying indoors meant that they could use AC. When going out, the destination was also chosen to be air-conditioned, *e.g.* to the gym, library, coffee shop or public spaces in malls. Another public space referred to was air-raid shelters originally built for the war with Japan (1931–45). Some of these civil-defence structures have since been repurposed and are a common meeting place for older people, offering passively cooled spaces in hot weather.

In addition to staying indoors, several participants described sending their children and/or parents to the mountains to spend the summer. When they themselves had to work, they would join them at weekends. The higher altitudes in the mountains offered cooler temperatures and protected the young and the old from the heat:

> Since my child is more than one year old, they will be sent to the mountains to escape the summer heat every summer. It is about a month or so. We will not go as a family. We have to go to work. Usually parents help take the children to escape the heat. On weekends, I will go there [and] stay […] for a day or two.
>
> (C-12M)

Some had bought summer houses in the mountains. Many of the participants left Chongqing in the heat of the summer when they had holidays from work, and they returned to home villages or visited other cooler regions in China.

3.2.3 Chongqing: impact of AC on work

With respect to work, a few participants mentioned that their organisation provided cold drinks and heatstroke prevention medication during hot weather. Some provided a hot-weather subsidy, *i.e.* a small payment to help defray the additional costs of AC. Several mentioned changed shifts for outdoor workers in construction, with breaks in the hottest part of the day, and a later shift continuing until 20:00 hours. The change in shifts could mean lower wages during the summer. For one worker who worked in retail, the central AC was switched off at 18:00 hours and this meant fewer opportunities for overtime work.

3.2.4 Chongqing: impact of AC on health

Alongside the dependence on AC, the disadvantages were also noted. In terms of health, participants felt that use of AC increased the likelihood of catching cold, and they attributed dry skin, constipation and respiratory tract problems to a drying effect. Some complained of an overly low AC setting and the difficulty of moving from a cold, air-conditioned setting to outdoor heat. A few participants were unhappy that reliance on AC entailed a lack of fresh air, and felt that this could contribute to chronic health problems. Several spoke of feeling uncomfortable in continuously air-conditioned rooms:

> People in a closed air conditioning environment, the air is relatively dirty, which will affect the mood, and cause breathing and physical discomfort to a certain extent.
>
> (C-21M)

3.2.5 Chongqing: implications for equality

There were indications that the benefits of AC may not be equally available to all. The increased cost of electricity bills due to AC were of concern to many of the participants, with summer bills being twice those of other seasons. Two participants showed awareness of the importance of a reliable power supply to enable AC, and of the high energy demands of extensive AC usage. Several participants voiced concerns about others, including construction workers and others working outdoors, delivery drivers, taxi drivers and cleaners:

> I think there are still many people working outdoors in hot days. They don't have access to air conditioning, for example, I often think of those elder uncles working on construction sites. They have to work on hot days to make a living.
>
> (C-10F)

3.3 LONDON

3.3.1 London: AC use in everyday life

In London, when asked what appliances, if any, they used to help cope with heat at home, none of the participants had AC. Most mentioned electric fans, although two participants had no appliances at all. Interestingly, many participants described their usage somewhat apologetically, as if they felt the need to justify their use:

> [we use fans at] only very specific times when having the window open is not enough [...] I try to use them as little as possible basically.
>
> (L-3M)

While a small number emphasised that they never used fans at night, others did, again justifying their use:

> but it was so hot, we had it on all night. Which yeah, we would never normally do that.
>
> (L-23F)

However, amongst those who did not have fans were those who were 'on the verge of getting some' (L-21M). Across all participants, there was little planning ahead for heatwaves.

The London participants relied heavily on natural ventilation to cool their homes. Almost all opened as many windows and doors as possible during the day. Some followed the sun in opening windows only when the sun was not on them, and closing windows when they were in direct sunlight. Many participants also used curtains or blinds to offer shade, with several keeping curtains or blinds closed throughout the day and a few also following the sun path for blinds. At night-time, almost all kept some windows open, although these were mainly smaller windows on upper floors, for reasons of security, noise and insects. Several participants were aware of the value of night cooling in helping to lower the temperature of the building.

3.3.2 London: impact of heat on lifestyle and health

The effect of heat on the London participants was similar to those in Dubai and Chongqing in some ways, but perhaps for different reasons. Most preferred to stay at home during a heatwave and they took less physical exercise. However, rather than attributing the desire to stay indoors to AC, they felt that the heat made them feel sluggish, tired or lazy, and they wanted to do less and move less:

> when it's humid, that's exhausting and you end up staying indoors [...] it just slows you down really mentally and physically.
>
> (L-11F)

In contrast to participants in Dubai and Chongqing who had AC in most or all rooms, many of the London participants had identified the cooler rooms in their homes and would spend more time there. This could be the kitchen, basement, living room or back bedroom. Some also sought comfort in the garden. If going out, some would seek out woods for shade or waterside locations, and a few mentioned locations with AC: the local supermarket, gym, cinema or shopping mall. Therefore, although there was appreciation of AC, lifestyles were not oriented towards its presence.

In the absence of AC in homes, the one health issue that was noted was the impact of heat on sleep quality. While this was not an issue in the interviews in Dubai and Chongqing, most London participants noted how their sleep was interrupted by hot nights and the negative implications:

> The issue is if you go to bed and you're still hot, you don't sleep and then you wake up the next day not in a particularly good state to start work.
>
> (L-15F)

For most, the sleep problems compounded their tiredness during hot days.

3.3.3 London: impact of AC on work and implications for equality

When the interviews were conducted, most London office workers were working from home due to pandemic restrictions. There were perhaps fewer mentions of AC at work than may have been the case at another time. Many of the participants described concentration problems in very hot weather and they were bothered by lower productivity: 'it's very difficult to kind of do a normal productive day's work' (L-3M). For those who could, they started work earlier, took breaks or finished earlier. A few participants were not office based and faced particular challenges: a plumber described being drenched in sweat for most of the working day; and a nurse talked about the additional challenges of wearing plastic protective equipment throughout a shift. These were examples of jobs that would not be easily resolved with room or building AC. In the case of the nurse in particular, the risks to the worker and consequent risks to patients from inadequate cooling provision were clear.

In addition to exploring how the participants dealt with extreme heat, the study also sought to capture their suggestions on how heat could be better dealt with in the future. The following section summarises their responses.

3.4 FUTURE MITIGATING STRATEGIES

Participants in all three locations were asked: What would help you the most to cope with the heat in future? The responses ranged from the technological to the social and behavioural. To help summarise the responses, ***Table 2*** presents a ranking, based on a count of mentions in the responses for the purposes of description.

Table 2: Rank order of suggested heat-mitigation strategies.

HEAT-MITIGATION STRATEGIES	DUBAI	CHONGQING	LONDON	TOTAL
Air-conditioning	1	1	1	1
Greenery	2	= 3	6	2
Urban planning	5	= 3	4	= 3
New technology	3	2	7	= 3
Buildings	–	4	2	4
Social routines	6	5	3	5
Reduce pollution and emissions	4	–	–	6
Notifications	–	–	5	7

In all three locations, the most frequently mentioned strategy was AC, including suggestions for healthier or more energy-efficient AC. In Chongqing, an associated factor was reducing the cost of electricity. More vegetation, especially trees, was important for Dubai and Chongqing participants but, interestingly, less so for London. Aspects of urban planning included more public shading, especially for public transport users, in Dubai; wind channels and better use of river water in Chongqing; and air-conditioned public transport and water points in London. Speculative new technologies were mentioned almost exclusively by the Dubai and Chongqing participants, including an artificial mountain to affect the weather in the former and artificial rain in the latter. Alterations to buildings were not considered in the Dubai responses, but better insulation and shading were mentioned by a small number of Chongqing and London participants, and London responses also included a need for better quality design of homes, incorporating passive design. In terms of social routines, there was mention of changes to working hours in all three locations. This strategy was more frequent in London responses, which also referred to working from home, and needing a culture which recognised the impact of heat. There was widespread awareness across all three locations of the role of climate change in the increasing frequency of heatwaves. A few London participants felt that advance notifications of heatwaves would help them to prepare, and in fact a heat-warning service was launched by the UK Meteorological Office in June 2020 (Ahmed 2021).

4. DISCUSSION AND CONCLUSIONS

Semi-structured interviews with a total of 72 participants in Dubai, Chongqing and London in August and September 2020 provided a rich view of experiences of living with and without AC. In Dubai and Chongqing, AC was ubiquitous, available in all participants' homes, most workplaces and many public buildings. Therefore, AC enabled life to go on and permitted indoor work to be little affected by heat. However, lives in Dubai and Chongqing in summer months were overwhelmingly lived indoors. It was a much more limited way of life than people in these cities enjoyed in cooler months. There was a sense of loss of freedom and a disconnect from the natural world. People took less exercise and felt less inclined to socialise. The evidence suggested that people had adapted to an air-conditioned lifestyle but adapted far less to the local weather. Indeed, other than a single mention of switching on the AC 'when I can't stand it' (C-18M) in Chongqing, there was no evidence of any attempts to build tolerance to heat. A Dubai participant suggested that residents had adapted to living in cold indoor conditions with AC on low settings, echoing earlier findings in the literature (Hitchings 2020, 2022). The implication was over-adaptation: using AC not to offset the worst heat nor to bring temperatures within a range of tolerability but to set the temperature to arbitrarily low levels. A study in Brazil similarly found that the lowest AC setpoint temperature was used in the hottest region (Ramos *et al.* 2021). As noted above, there was even an element of boasting from one participant who detailed the extra clothing she needed at night due to AC-induced low temperatures, in line with earlier findings of excessively low night-time AC settings in Oman (Majid *et al.* 2014).

Such adaptation represents a regressive step in a warming world. The human body can adapt to heat, and this is evidenced by findings showing higher thermal comfort thresholds in summer in countries without extensive AC (DeDear & Brager 2002) and more recent work on heat acclimatisation (Candido *et al.* 2012). In addition to the physiological stress and discomfort caused by moving between extreme temperatures, noted by many participants, continuous use of cold AC is likely to hinder acclimatisation to local weather (Yu *et al.* 2012) and lead to higher sensitivity to heat among those with long-term exposure to AC (Buonocore *et al.* 2019). With a view to reducing dependence on AC, this is a topic that both policy and technology could address. Regulation and industry change to increase minimum setpoints could force a move away from unnecessarily low temperatures. Dynamic temperatures settings for AC that move in line with outdoor temperatures could offer at least a minimal level of acclimatisation. Previous work on changing setpoints has tended to focus on energy efficiency (Xu *et al.* 2020b) or optimising both efficiency and occupant thermal comfort (Kim *et al.* 2020). The findings here additionally note the need for acclimatisation to hotter weather (rather than cold indoor settings) and this is an additional benefit. Public health information and behaviour change interventions could seek to shift norms and discourses by addressing AC settings, and the evidence here suggests that a focus on the health and comfort benefits of acclimatisation would resonate with many AC users.

An important finding from Dubai and Chongqing was the extent to which people do not experience AC as providing a comfortable environment. Even where participants acknowledged their desire for and dependence on its cooling, many expressed their dislike of the experience. The challenge of negotiating the desired temperature, with family members at home or colleagues in the office, meant that not everyone was content with the outcome, adding to the findings of Sintov *et al.* (2019) who also noted the need for negotiation of thermal comfort within households. There was a general sense from many participants that they felt that continuous AC was unhealthy, creating overly dry indoor conditions with poor air quality. This was in addition to a list of health complaints from AC use in general and from moving between temperature extremes in particular. The authors propose that the term 'thermal comfort' is not appropriate for all AC, despite it being an objective of the technology. It would be appropriate for researchers and policymakers to move away from terms referring to comfort, which can be traced back to 20th-century industry marketing (Ackermann 2010) and to revert to terms relating to avoidance of heat stress, environmental conditioning or cooling services as more accurate. This could be part of a move to reconstruct AC as a useful technology for specific and limited services, and not the sole or inevitable solution to extreme heat (Walker *et al.* 2014).

Although AC enabled productive indoor work in Dubai and Chongqing, AC was not equally accessible to all. The cost of running AC was an issue for Chongqing participants. Outdoor workers in particular were seen not to benefit from AC, and the participant who lived in overcrowded accommodation, with potentially intermittent AC, and who travelled on public transport, pointed to different experiences for different socio-economic groups. Interestingly, holiday travel away from the heat was common in both Dubai, a relatively new city, and Chongqing, established long before the advent of AC. Long-distance holidays and the purchase of summer houses in the mountains in Chongqing are likely to be available only to the affluent. Similarly, air-conditioned public spaces operated as for-profit enterprises, as hotels, gyms and cinemas are, may not be equally accessible to all socio-economic groups. The public spaces within shopping malls, and the repurposed civil-defence structures in Chongqing, offered alternative cool places. Although cool spaces have been used in European cities in recent heatwaves, urban planning should address the need in a strategic way. Adequate and planned provision is necessary rather than reactive emergency measures, and accessibility to all socio-demographic groups should be a priority. These points have been examined by Bolitho & Miller (2017) in an Australian context and align with the UN National Cooling Action Plans framework (Cool Coalition 2022), but bear repetition in each new context explored.

Participants in Dubai and Chongqing were open about their dependence on AC, and their continuous daily and seasonal use. This underlined the contrast with the London participants who seemed almost apologetic, seeking to justify their usage of fans in the home. This suggests quite different cultural norms, with AC wholly culturally embedded in Dubai, almost equally embedded in Chongqing but a reluctance to depend on technology in London. There is still opportunity in London, and potentially other temperate regions, to develop cultural norms in dealing with heat that avoid ubiquitous reliance on AC. However, although the London participants did not have AC, some were contemplating its purchase. There was strong evidence in the data that participants did not prepare for heatwaves in advance. Combined with evidence that sales of AC units tend to increase rapidly during hot weather (Cuff 2020), it can be suggested that a prolonged heatwave could trigger a rapid change in behaviour, with those who have been contemplating buying cooling appliances prompted to do so. Therefore, although there is, as yet, time to develop solutions that avoid AC dependence, a sudden upsurge in purchasing within a short period of time is possible. The challenge for policymakers is to encourage householders and developers to prepare homes now. In the absence of knowledge of how, for example, shading or passive design can aid cooling (Wang *et al.* 2021), the vacuum will be filled by impulsive purchases of AC.

The absence of technological solutions to heat for the London participants meant more active behavioural and social adaptation. These included changes in clothing, food and drink, rooms occupied, use of curtains and blinds, and specific behaviours to reduce heat, such as applying cold contact to the body. There was more awareness of the interaction of the home with the physical environment, such as sun path, night cooling and cooler spaces indoors. Participants described working from home and shifting work hours. This points to behaviours and social patterns that could be adopted and also to aspects of housing design to cope with heat, including the provision of central, shaded 'cool spots' as well as better insulation and shading (Porritt *et al.* 2012). There is a particular need for better design for bedrooms. Single-family homes over two levels in London almost exclusively have bedrooms on the upper floor and the increasing number of loft conversion exacerbates the challenge (Li *et al.* 2019; Drury *et al.* 2021). The accumulation of rising heat poses a problem for comfort at night and, as noted above, the lack of sleep is a particular risk in terms of ability to focus on work the next day.

The participants' suggestions for future mitigation of heat showed interesting differences. It was noticeable that urban greening featured more for Dubai and Chongqing participants than for those in London. It is possible that more London participants lived in suburban areas with private, vegetated gardens, rather than in high-rise, multiple-occupancy buildings common in urban areas in Dubai and Chongqing. Equally, a study in subtropical Fukuoka, Japan, noted that the use of vegetation for shading may be a culturally established cooling practice (Kondo *et al.* 2021) that is more common in hot climates than in temperate. The findings suggested a lack of awareness among London participants of the potential for greenery, especially trees, to provide shading and for evapotranspiration to aid cooling (Viguié *et al.* 2020). Urban planning guidelines require revision to increase levels of trees and vegetation along streets.

The participants' ideas showed scope for better urban planning for heat, and that this should be based on locale and take advantage of natural resources such as rivers. The potential for water-based strategies was noted by the participants: provision of public water points, water spraying of public areas, which already takes place in Chongqing, and more water features in urban design, although one Dubai participant cautioned about increasing humidity. Public transport was a priority, with heat protection needed not only in the vehicles themselves but at the waiting points too. While some London participants were aware of the potential for better design of homes to provide heat protection, this knowledge was missing in the Dubai responses: there was mention of floor-to-ceiling glazing without external shading, but no comment on the unsuitability of such design for hot climates. Clearly, a fundamental step to reducing dependence on AC is a set of building and planning regulations that guide building and urban design towards solutions that are appropriate for the context. The 'international style' first documented almost 90 years ago, which prides itself on transcending regional identity and climatic context (De Wit 2018), must be superseded by design that is climatically and culturally appropriate in enabling life in extremes of heat without continuous AC. In temperate climates, passive measures such as shading on homes can offer significant benefits (Porritt *et al.* 2011), but the evidence suggests that this knowledge is not shared amongst the general public. Finally, all participants could see benefits in more flexible social routines, particularly around working hours, which responded to the heat. Reducing working hours in very hot weather, and shifting some work to cooler morning or evening times, would enable better coping and potentially higher productivity. Developing seasonal work patterns could facilitate greater comfort and resilience.

As with all studies, there were limitations to the research reported here. Housing and neighbourhood form are known to influence use of AC in new and retrofit projects (Noonan *et al.* 2015), but the data here collected only basic information on housing type. The planned quotas for participation were not wholly achieved, with a predominance of the 30s age range in Dubai, and of men under 40 in Chongqing. This limited the 'adequate data' requirement of fidelity and the findings should be considered in light of the participants interviewed. In addition, convenience recruitment can lead to the potential bias that participants may be drawn from a limited socio-economic band, similar to that of the researchers. While a range of professions was included here, this should be more rigorously pursued in future research, with quotas for different household incomes. In particular, lower income individuals may be more likely to have limited access to AC at work (*e.g.* construction or delivery workers), and examining the experience of more vulnerable groups in middle- and higher income economies is essential for the evaluation of heat-related social risk.

In keeping with the phenomenological approach to the study, proposals for future work centre on individuals and households. More work is needed on how to encourage householders to make modifications to their homes which would reduce dependency on the use of AC as well as the cooling load, *e.g.* the addition of shading vegetation or water features. Detailed work is needed on communications, in policy, professional education and marketing, aimed at shifting discourses away from AC as essential, as the only solution and as an adequate solution. Future work with householders, health professionals, consumer groups, designers and others aimed at challenging AC as equating to 'thermal comfort' could broaden perspectives to include behavioural and social, built environment and technological solutions to future heat.

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AUTHOR AFFILIATIONS

Niamh Murtagh *orcid.org/0000-0002-5466-3606*
The Bartlett School of Sustainable Construction, University College London, London, UK
Sulafa Badi *orcid.org/0000-0002-3810-170X*
Faculty of Business & Law, The British University in Dubai, Dubai, United Arab Emirates (UAE)
Yaling Shi *orcid.org/0000-0002-6120-9161*
Faculty of Architecture and Urban Planning, Chongqing University, Chongqing, China
Shen Wei *orcid.org/0000-0001-9644-5095*
The Bartlett School of Sustainable Construction, University College London, London, UK
Wei Yu *orcid.org/0000-0001-6515-2257*
Department of Building Environment and Equipment Engineering, Chongqing University, Chongqing, China

COMPETING INTERESTS

The authors have no competing interests to declare.

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Ethical approval for the full study was given by the University College London BSSC Ethics Committee (reference number 2020-Stf-NM-001).

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