



Red Alert:

Developing a human-centred
national *Heat Resilience Strategy*

November 2023

Acknowledgements

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Foreword

The UK has a proud history of action in the fight against climate change.

The UK was the first major country to establish a clear governance framework to achieve emissions reductions when it legislated the 2008 Climate Change Act, creating the Climate Change Committee (CCC), of which I was an inaugural member. Over that time, we've seen a huge leap forward in global ambition to tackle climate change. The path to a Net Zero UK is now feasible and affordable, something that looked almost impossible just a decade ago. So, positive progress with ambition, but we still need to accelerate action.

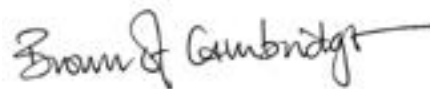
Back in 2008, adapting to the changing climate in the UK felt like a problem for the future. I now chair the CCC's Adaptation Committee, which assesses the risks from climate change facing the UK and how well the country is preparing for them. It is becoming increasingly clear that climate change is already impacting the lives of people here. UKHSA data tell us that across all five heat-periods of 2022 – those summer hot spells in the year when the UK first experienced temperatures of over 40°C – the estimated total excess mortality in England was 2,985 for the most vulnerable age group (those aged 65 years and over), the highest number since the introduction of the Heatwave Plan for England in 2004. These are avoidable deaths resulting from the impact we are having on our climate.

Extreme heat is also having an impact on the productivity and health and well-being of the whole nation. Extreme heat is dangerous not just because it can be lethal in the short-term but also because it can worsen outcomes for a wide variety of the public – be it people with pre-existing health conditions,

those who are pregnant, or those who work in conditions where they are unable to adapt their environment to fall within human heat tolerance for comfort, such as outdoor workers.

That is why this report from The Physiological Society and the Faculty of Public Health is so timely. It recognises that while progress has been made in some areas in response to extreme heat, we must go further to ensure that there is an integrated response across government and other responsible organisations that is grounded in an understanding of the human capacity to respond to extreme heat.

As a scientist myself, and in my various current roles, I see the critical role that research plays in the development of science-based solutions to the major challenges facing us as a nation and a species. Just as we need rapid, collective action to limit carbon emissions to meet the Paris Agreement target of limiting warming to 1.5°C, we must also work together to adapt, to ensure that our response to more frequent and intense extreme weather events provides protection to those most vulnerable and most exposed to them. Putting physiology and human health at the heart of our response will be critical.



Julia King, Baroness Brown of Cambridge
FREng, FRS, FMedSci

Chair, Adaptation Committee of the Climate Change Committee.

Chair, House of Lords Science and Technology Select Committee



Co-Chairs' foreword

As part of the Paris Agreement, governments around the world, including the UK Government, have committed to 'limit global warming to 1.5°C above pre-industrial levels'.¹ Putting to one side the urgent changes required to meet this ambition by 2030, this average temperature goal obscures the extreme variations of temperature throughout the year and across the globe that are associated with it.

Missing this target will have a significant impact on the UK population's health and well-being as well as lives and livelihoods. The UK ranks joint-first globally in the countries that will suffer the highest relative increase in area-weighted mean cooling degree days (CDDs) with an increase from 1.5°C to 2.0°C above pre-industrial levels.² This means that we will experience increasingly frequent and intense periods of extreme heat that will challenge our ability to cope, particularly for those who are particularly vulnerable due to physiological or environmental reasons.

We are already beginning to witness our climate changing. 2022 was the UK's hottest year on record, with an average temperature of over 10°C recorded for the first time. Globally, 2023 and 2024 are predicted to be hotter still.³

Simultaneously, we are also seeing the human health impact of this heat. During the extreme heat of summer 2022, there were an estimated 2,985 (2,258 to 3,712) all-cause excess deaths associated with five heat episodes in England, the highest number since the introduction of the Heatwave Plan for England in 2004⁵. These deaths were mostly among vulnerable groups, due to either reduced physiological capacity to cope with extreme temperatures or living and working in environments that are utterly inappropriate for the rising temperatures. These include people who are pregnant, people with pre-existing health conditions or who take certain medications, and those exposed to higher temperatures at work or due to lack of shelter (such as people who experience homelessness).

Physiology and physiologists have a crucial role to play in responding to this. As decision makers across the UK grapple with the pernicious effects of climate change, we must ensure that we adopt a human-

centred approach to heat resilience considering the multiple factors that influence vulnerability and the inequalities in their distribution across the population. Physiologists and public health professionals need to collaborate to protect the population from the harmful effects of heat. On one hand, better understanding of our physiological response to heat and safe, stress-free body temperature thresholds can maximise the effectiveness of public health interventions. On the other hand, we also need to understand how people behave in response to heat in their environments, and consider the inequalities in the distribution of vulnerability across the population. Building heat resilience equitably at the societal level will require a combination of individual and structural approaches and, hence, the combined expertise and experience of physiology and public health professionals.

We will conclude our remarks with a quote from the UKHSA from their 2022 Heat Mortality Monitoring Report:

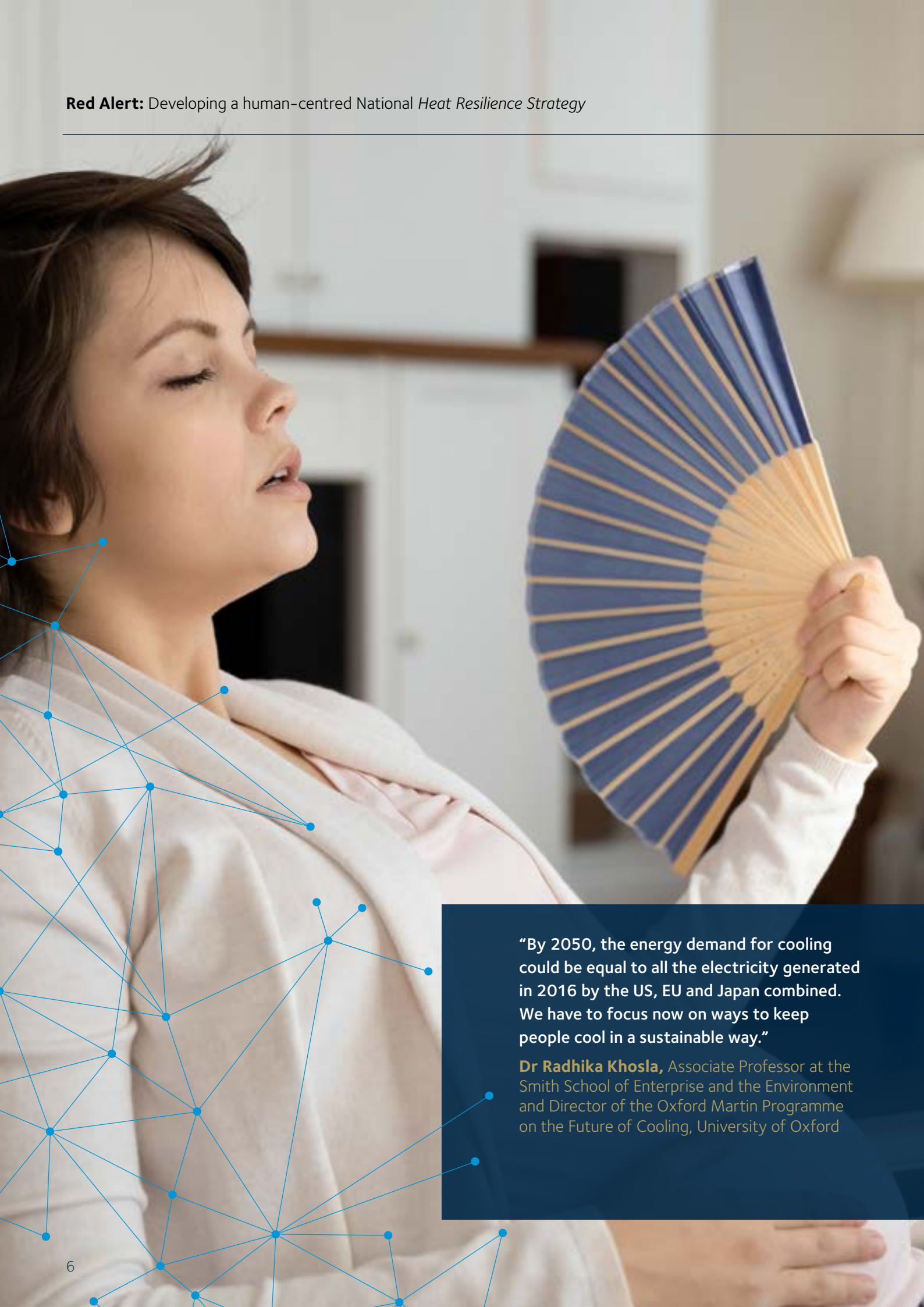
Heat episodes in England are becoming more intense, longer and more frequent...Therefore, it is increasingly important that organisations ensure they have heat response plans in place... as well as longer-term adaptation strategies to mitigate the impacts across all sectors to reduce the number of avoidable deaths during adverse heat events in the coming years.⁶

Professor Mike Tipton

Professor of Human & Applied Physiology at the Extreme Environments Laboratory at the School of Sport, Health & Exercise Science, University of Portsmouth
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“By 2050, the energy demand for cooling could be equal to all the electricity generated in 2016 by the US, EU and Japan combined. We have to focus now on ways to keep people cool in a sustainable way.”

Dr Radhika Khosla, Associate Professor at the Smith School of Enterprise and the Environment and Director of the Oxford Martin Programme on the Future of Cooling, University of Oxford



1. Rising temperatures and the need for a *Heat Resilience Strategy* in the UK

1.1 What is the extreme heat challenge currently facing the UK?

Global temperatures continue to rise, and 2023 is set to be the hottest year on record. All animals, including humans, depend upon a stable and narrow range of environmental conditions to thrive and survive. By changing background 'stable' temperatures in such a rapid timeframe over the next 50 years, 1 to 3 billion people around the world are projected to be left outside the climate conditions that have served humanity well over the past 6,000 years, and without action, a substantial part of humanity will be exposed to mean annual temperatures warmer than nearly anywhere today.⁴

Individuals and communities across the UK are already experiencing increasing frequency and impact of extreme heat, and this is set to intensify in the years ahead.

In 2022 the UK experienced record-breaking temperatures of over 40°C, resulting in the Met Office issuing its first 'red warning' for extreme heat and the Government declaring a national emergency. The consequences of climate change today mean that higher temperatures in the UK are no longer isolated

to occasional heatwaves during July and August.⁵ September 2023 was the hottest September on record, with daily maximum temperatures exceeding 30°C somewhere in the UK for seven consecutive days. The UK will have the joint-highest relative increase in area-weighted mean cooling degree days (CDDs) with change in global temperature increasing from 1.5°C to 2.0°C.⁶ This will lead to an increased demand in energy-intensive cooling methods given the current temperatures and environments that the UK is prepared for.⁷

Cooling Degree Days

A cooling degree day (CDD) is a measure used to assess and predict the cooling needs of different regions, based on how hot the outside air temperature is in relation to the designated standard temperature for the region.

The higher the outside temperature on any given day, the higher the number of CDDs, and generally the higher the energy consumption required to meet the cooling needs of the region.⁸

"The UK saw massive amounts of disruption in the record-breaking heatwaves of 2022. Extreme heat can lead to dehydration, heat exhaustion, and even death, especially in vulnerable populations. It's a health and economic imperative that we prepare for more hot days."

Dr Nicola Miranda, Senior Researcher at the Oxford Martin Programme on the Future of Cooling, University of Oxford

"If we adapt the built environment in which we live, we won't need to increase air conditioning. But right now, in countries such as the UK, our buildings act like greenhouses – no external protection from the sun in buildings, windows locked, no natural ventilation and no ceiling fans. Our buildings are exclusively prepared for the cold seasons."¹⁰

Dr Jesus Lizana, Senior Research Associate at the Oxford Martin Programme on the Future of Cooling, University of Oxford

Researchers from the University of Oxford found that the UK is one of the most 'dangerously unprepared' countries for heat if the international 1.5°C barrier is broken⁹ because of a lack of prioritisation of heat within the UK's built environment. While Central Africa is set to see the most extreme temperatures, the biggest increases in days requiring cooling will be seen in Northern Europe, with the UK forecast for a rise of 30% in days when cooling is needed.

Besides the adverse health consequences, which at their most severe result in death, heat also has economic consequences, for instance, due to productivity losses or degradation and destruction of crops, farmland and infrastructures. It is estimated that in 2022 heat exposure led to the loss of over 11 million potential work hours in the UK, nearly four times as many as the annual average from 1991-2000.¹¹

It is thus unsurprising that climate change is currently the second biggest concern facing adults in Great Britain (74%) and that rising UK temperatures is the biggest impact of climate change that adults expect to experience by 2030 (75%).¹² Furthermore, 62% of adults in the UK are concerned about the impact of heat events on themselves.¹³ The impact of heat is a concern right across the UK, with the UK Climate Change Committee reporting that in Northern Ireland 32% of those surveyed had personal experience or know someone who experiences serious health impacts from heatwaves.¹⁴ In Scotland, heat related hospitalisations and deaths have risen markedly in recent years and are forecast to continue to rise.¹⁵ Adaptation is, thus, required across the UK to protect population health from the detrimental impact of extreme heat.

Policy and practice concerning temperature resilience in the UK has focused historically on our response to cold, and equivalent guidance and legislation. The time is now for the UK to respond quickly and effectively to extreme heat.

However, it is important to be clear that adaptation is not a substitute for effective and rapid mitigation through decarbonisation. Breaching the international commitments agreed in the Paris Agreement will exceed our ability to adapt as a species and planet. This existential threat is being driven by continued greenhouse gas emissions, which are currently on course to exceed these internationally determined parameters.

1.2 How can the UK develop a successful *Heat Resilience Strategy*?

We call for the Government to urgently develop a human-centred multi-stakeholder *Heat Resilience Strategy* that is rooted in the needs of those most vulnerable to the impacts of extreme heat.

The recent publication of the Adverse Weather and Health Plan by UKHSA and the creation of the UKHSA Centre for Climate and Health Security, as well as the Health-health Alert Service are important and welcome steps in improving the capabilities of the UK to respond to extreme heat.

A *Heat Resilience Strategy* must build on the physiological understanding of the human body's response to heat and requires collaboration and input from governments across the UK and civil society stakeholders. The key stakeholder areas include physiology, public health, occupational health, urban planning and building regulations. It will also require better integration and collaboration with other research domains (e.g. Earth sciences and behavioural sciences) and with meteorological surveillance.

Report methodology

This report aims to demonstrate why research and expertise in physiology will be essential in supporting each of the stakeholder groups identified above in their responsibilities within an effective National *Heat Resilience Strategy*, by identifying:

- Those most at risk of adverse health outcomes associated with extreme heat and the mechanisms that increase this risk.

Summary of report recommendations



Research

Establish a Heat Adaptation Research Exchange Taskforce, chaired by the Cabinet Office working closely with other government departments and devolved administrations. This Taskforce will tackle research gaps and increase the speed of research translation into policy and action.



Built environment

Form a Human-Centred Adaptation Design and Planning Institute to accelerate the adaptation of the built environment to higher temperatures, with governments across the UK mandating thermally efficient design principles and promoting the use of green infrastructure.



Business

Require all employers to develop a physiologically-informed and sustainable plan for workers during extreme heat events to protect health, safety, wellbeing and productivity including introducing statutory guidance on maximum temperatures for different levels of activity and types of Personal Protective Equipment worn.



Public health

Bring together public health professionals from across the UK and devolved governments, local authorities, and charities to deliver a public health campaign and expanded early warning systems focused on supporting vulnerable groups to improve their long term resilience to heat and preparedness for heatwaves.

- The critical gaps in current policy and research understanding around heat resilience.
- The broad range of settings, current regulatory frameworks and public health guidance in which physiological expertise can be applied to improve heat resilience.
- Interventions that can help the population mitigate, adapt and prepare for extreme heat events without increasing our demand for carbon-intensive interventions.
- Case studies which demonstrate how heat resilience is already being built into public health strategies and the care of those most vulnerable.

1.3 Why is physiology essential to a National *Heat Resilience Strategy*?

Physiology is the science of life: it is the branch of biology that aims to understand the mechanisms of living things, from the basis of cell function to the integrated behaviour of the whole body and the influence of the external environment. Physiology helps us to understand how the human body works in health and how it responds and adapts to the challenges of everyday life.

The response of the body to increased heat

In terms of thermal physiology, the body attempts to maintain a relatively narrow safe resting body temperature range of 36.1–37.2°C.

How people are affected by increased heat in their surroundings is influenced by temperature, humidity, air movement, solar load (heat gain from the sun), and a range of factors including age, the activities they must undertake, (protective) clothing, fitness and previous exposure and the interaction between heat, medications and pre-existing health conditions.

As temperatures rise, heat receptors on the skin detect the change at the skin surface and send messages to the brain. This increased heat exerts a

range of physiological stressors on the human body, and physiological and behavioural responses result, which are designed to maintain a stable internal core body temperature. However, such responses can cause harmful physiological stress, whilst death can also result if limits to adaptation are exceeded.

In response to heating, the body tries to dissipate its internal heat by widening blood vessels (a process called vasodilatation) in the skin and cooling the skin by sweating. However, excessive heat and/or humidity can overwhelm these regulatory systems. This can result in heat cramps (muscle spasms) or heat exhaustion with symptoms including fatigue, dizziness and nausea. This condition can escalate to heatstroke, which is a life-threatening condition.

These physiological responses are necessary to limit elevations in deep body temperature. The redistribution and increased blood flow to the skin, due to cutaneous vasodilatation, increases cardiac demand while decreasing the heart's filling pressure. These responses require the heart to pump harder and faster, increasing the heart's oxygen demand.¹⁶ The production of sweat also requires additional rehydration and electrolytes to replace the fluids and salts lost through sweating.

This fluid loss, coupled with the body's inability to cool down effectively, can impair vital organs, cognitive function and thermal comfort/well-being.

The physiological responses to increasing body temperature are supported or challenged by environmental factors and behaviour which make these responses more or less effective. For example, personal protective clothing and equipment (PPE) is often poorly ventilated, which makes it harder for the body to lose heat to the environment through evaporative and non-evaporative routes. However, where there is no requirement for PPE, certain looser fabrics can support these responses, as can rehydration and building physiological resilience through physical fitness, and sustainable nutrition to reduce the additional stresses being placed on the body during extreme heat.

The majority of deaths and adverse health outcomes due to extreme heat are preventable, often using very simple measures that can be targeted at the individuals and communities we know to be at the highest risk. These include ensuring adequate hydration and ensuring people are not overexposed to extreme heat, but also not taking away all heat or climate stimuli, which would limit longer-term physiological resilience achieved through acclimatisation.

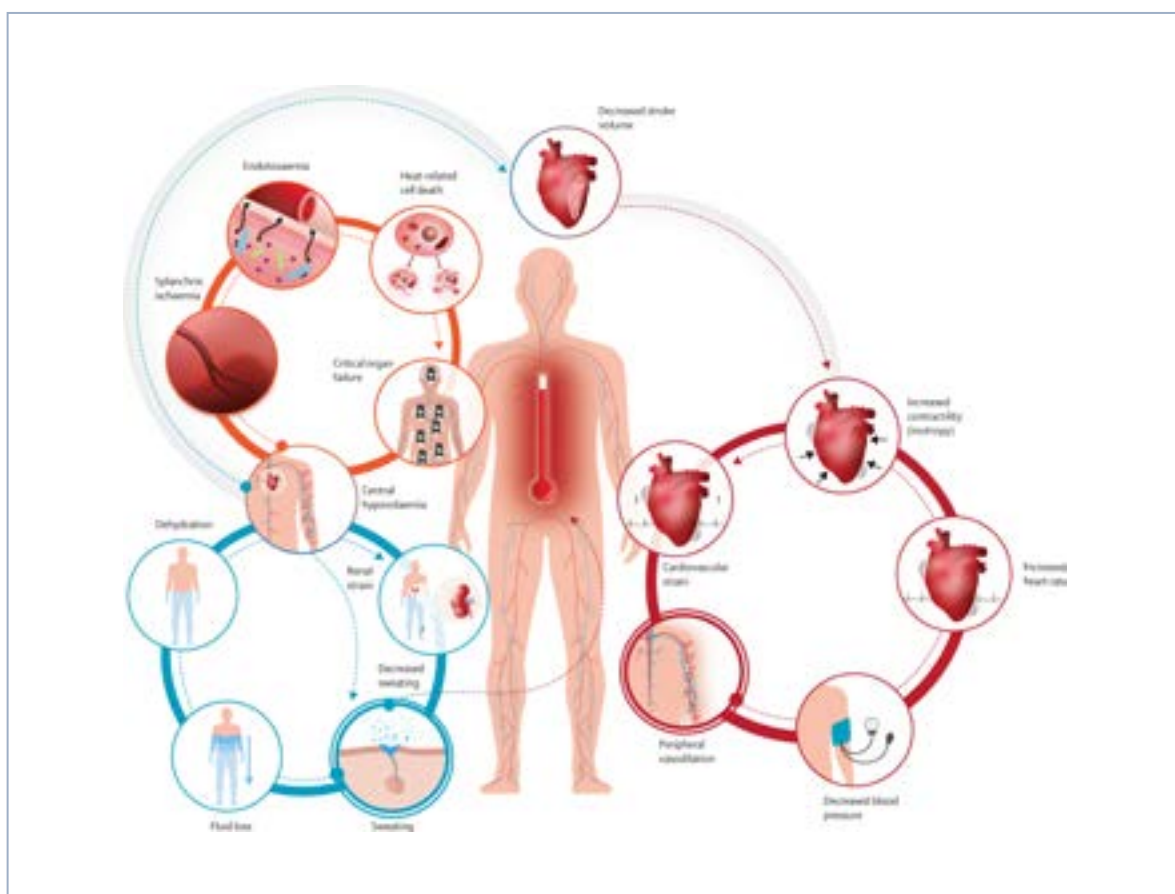
Understanding the physiological response to heat will be critical to the national response to the challenges posed by rising temperatures, and therefore we have placed physiology at the heart of the proposal in this report for a human-centred National *Heat Resilience Strategy*.

The link between fitness and heat resilience

Physical fitness is important to overall health and wellbeing, and people who lack fitness will find that they are physiologically less able to respond and adapt to increased heat. This leaves them more vulnerable to health complications as heat increases.

As a consequence of being unfit, a person will have a less efficient cardiovascular system. This limits the ability of the body to distribute blood to be cooled at the skin and support vital organs. A smaller blood volume compounds this inefficiency, which reduces the ability of the body to dissipate heat.

As discussed above, sweating is an important physiological mechanism to cool the body, and unfit



Credit: The Lancet



people often have reduced sweating capacity and efficiency. Higher percentages of body fat, or adipose tissue, will increase workload when exercising as well as act as an insulator, which makes it more difficult for the body to off-load heat. It is also the case that adipose tissue has lower blood flow than muscle tissue, compounding the increased challenge to remove heat from the body.

Regular exercise provides many associated thermoregulatory benefits (e.g. increased blood volume, improved sweating, more robust cardiovascular system), as well as the partial heat acclimatisation that comes from exercise-induced body temperature increases.

People who do not undertake regular exercise will not have these benefits, and less fit individuals already operate closer to their physiological limits during everyday activities, making added stressors like heat particularly taxing. It is important to note the link

between underlying health conditions and fitness, as often a lack of physical fitness is a consequence of other health issues, but taken together this can intensify susceptibility to heat.

Improving physical fitness can bolster resistance to heat stress but cannot be left to the individual alone. We must support the public, especially those who are likely to be less physically active, to be aware of the risks associated with a sedentary lifestyle. Inequalities in sport and physical activity mean that people in lower socioeconomic groups are least likely to be active. We also know that activity levels generally decrease with age, with the sharpest decrease coming at age 75+.¹⁷

Public health agencies must do more to ensure these groups have access to scientifically rigorous advice on health and well-being as it relates to physical activity and nutrition. There is a close link between physical and mental health and The Physiological Society's

2021 report, *A National Post-Pandemic Resilience Programme*, highlighted the decline in older adults' mental health, due to a reduction in physical activity during the COVID-19 pandemic. Exercise improves mental health by reducing anxiety, depression and negative mood and by improving self-esteem and cognitive function.

An interdisciplinary approach to developing interventions to improve heat resilience of vulnerable groups

Improving resilience to heat is multifactorial, requiring a deep understanding of how physiological factors are affected by environment and behaviour. Physiology is uniquely placed to help integrate and expand upon siloed policies around our response to heat.

For example, physiological understanding of determinants of thermal comfort, variation with exercise and adaptation to heat can be used to inform and shape policies and interventions around building regulations, urban design, public places, and work and care settings by supporting a better understanding of human tolerance and comfort. This can be used to develop more sustainable, equitable, cooler environments through the use of green space and passive cooling.

This is of crucial importance for improving resilience in the workplace through the development of physiologically-informed and sustainable plans for workers during extreme heat events to protect health, safety, wellbeing and productivity.

For example, physiologists have assisted emergency service workers and the armed forces to develop criteria for work/rest scheduling and the use of PPE during extreme weather based on an understanding of how the combination of external challenges (heat, humidity, clothing) and internal factors (work intensity, fitness) combine to challenge an individual's thermoregulatory system and ability to work in any given environment.

Supporting a virtuous, rather than vicious, response

The need for sustainable approaches to increasing resilience are even more important in the context of the need to limit our greenhouse gas emissions. Physiological research has the potential to inform a 'virtuous combination' of interventions where public health guidance and the built environment, with coordination and incentivisation from government, can improve our resilience while reducing our carbon footprint.

This virtuous combination of adaptation and mitigation to the climate emergency will make our environments more hospitable, widening the opportunities for people to access the benefits of physiological interventions. Adaptation and mitigation need to occur in unison to ensure people remain cool while not undermining efforts to reduce carbon emissions.



“The vast majority of heat deaths are preventable, often using very simple measures that can be targeted at people we know are at highest risk.”

Professor Lea Berrang Ford, Head of the UKHSA Centre for Climate and Health Security and a Priestley Chair in Climate and Health at the Priestley International Centre for Climate, University of Leeds¹⁸

Credit: Centre for Ageing Better

2. Increasing the resilience of those most at risk

2.1 Defining vulnerability

Some communities and populations are more vulnerable to the impact of heat exposure than others because of a lack of physiological resilience as a result of their health or inability to respond physiologically to extreme heat.

Others are vulnerable because their environment or behaviours do not support their body's physiological response to heat. This is because they are less able to maintain or improve their physiological resilience or to change their behaviour or circumstances to adapt to extreme heat exposure.

In order to adequately develop a robust heat resilience policy that will support all people living in the UK, it is imperative that the focus of research and action is directed towards those most at-risk from extreme heat exposure. This requires a consideration of physiological and environmental perspectives and, in particular, those living at the intersection of multiple vulnerabilities. These vulnerable groups will change in priority depending on the scenario in question.

Physiological vulnerability is the inherent or acquired characteristics of an individual's body that affect their

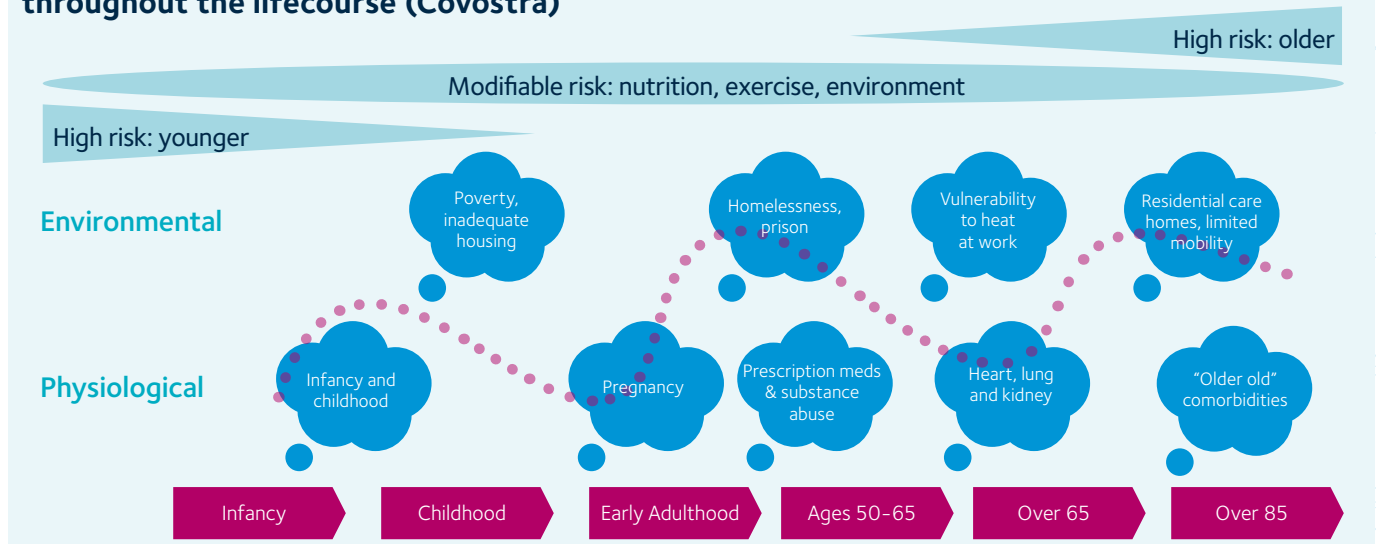
autonomic ability to cope with heat, such as age, health conditions, physical fitness or acclimatisation.

Environmental vulnerability pertains to the external conditions and factors in an individual's surroundings that increase the risk of heat exposure and its adverse effects because the individuals are unable to respond behaviourally to physiological inputs.

Many physiological risk factors, e.g. co-morbidities, are the physical manifestation of a complex set of interactions between poor diet, physical inactivity, working in unsafe environments, poverty and limited access to education. Those same environmental factors influence people's ability to respond to extreme heat events at an individual level (e.g. awareness about protective behaviours) and at a structural level (e.g. housing conditions, urban heat islands, lack of green space in almost all urban centres, particularly where poorer communities live). This means that a comprehensive understanding of how health inequalities manifest and can be effectively addressed must be at the heart of any successful *Heat Resilience Strategy*.

From infancy to old age, there are a range of risk factors that can arise at different stages during a person's life (see Figure 1).

Figure 1: A visualisation of physiological and environmental risk factors throughout the lifecourse (Covostra)



2.2 Physiological vulnerability

Most people are physiologically able to sense rising temperatures and take a combination of physiologically-driven autonomic (e.g. sweating) and behavioural (e.g. seeking shade) responses to adapt to extreme heat, particularly within the UK.

However, there are vulnerable groups that are less able to combine these physiologically-driven automatic and behavioural adaptations owing to reduced physiological resilience, biological responses that make them more susceptible to heat, or a lack of capacity to adapt their environment.

Often these vulnerable groups are also the groups for which there is a lack of robust research-based evidence and understanding of the full extent of heat's impact, their unique susceptibilities, and the best mitigation strategies. Physiologists are able to perform studies that simulate the types of extreme conditions people are exposed to and measure how different heat interventions influence the physiological strain (such as increased heart rate, body temperatures, regional blood flows) that develops during heat exposure and that ultimately leads to health consequences.

Therefore, a successful *Heat Resilience Strategy* should be broad enough to improve the resilience of the whole population, while also focusing on the most vulnerable groups. For these groups it should both identify the gaps in the knowledge base and utilise existing knowledge to best construct an effective response.

“Explicit attention should also be given to address inequalities in health that would help reduce the burden of climate change on the population and ensure that health co-benefits of adaptation actions across other sectors (such as adapting the built environment) are maximised.”

UK Climate Change Committee,
Progress in adapting to climate change 2023
Report to Parliament, March 2023¹⁹

Older people

The UK population is ageing, with the number of people aged 65 years and over in England and Wales increasing from 9.2 million in 2011²⁰ to over 11 million in 2021. In mid-2020 there were 1.7 million people aged 85 years and over, making up 2.5% of the UK population.²¹ By mid-2045, this is projected to have nearly doubled to 3.1 million, representing 4.3% of the total UK population. Between 2013-2022, total annual days of exposure to heatwaves increased 92% for adults over age 65 in the UK, compared with 1986-2005.²²

The human body's ability to thermoregulate declines with age, meaning that older people are at much higher risk of adverse outcomes from extreme heat exposure: a 1°C temperature rise has been shown to increase cardiovascular, respiratory and cerebrovascular mortality among older people.²³ Thermoregulation becomes less effective as the other body systems it uses, such as the cardiovascular system, deteriorate with age. We must also recognise that there are sex-based differences in how we experience heat as we age, with changes in heat perception during and after menopause still poorly understood and little researched.²⁴

Furthermore, the thermoregulatory effects and consequences of ageing may be further compounded by a higher likelihood of chronic diseases such as diabetes,²⁵ and older people are at a higher risk of dehydration due to a reduced capacity to behaviourally thermoregulate through independent fluid intake. Effects of chronic dehydration can include heatstroke, constipation, dementia, cognitive function and thromboembolic disease.²⁶

Older people are more likely to have impaired cardiovascular function as well as increased incidences of cardiovascular and respiratory illnesses. They are also more likely to be taking prescription medications, of which little is known about they may limit or compound the physiological response to heat.²⁷

Gaps in our understanding of the impact of heat, especially chronic heat exposure, on older people

remain. There is a lack of data on the impact of heat on older people, with research tending to be conducted on and based on the response to heat from young, fit trial participants. This is further complicated when endeavouring to separate the effects of ageing from the effects of age-related disease, as older people with co-morbidities are more likely to fail the physical elements of trial inclusion criteria.

Pregnancy

“The greatest driver of vulnerability is the over-65s (...) Even if we are doing a good job of adapting, we are facing a battle that is demographic. It is important to remember in this space that age is the greatest risk, but it is also the greatest opportunity for targeting support.”

Professor Lea Berrang Ford, Head of the UKHSA Centre for Climate and Health Security and a Priestley Chair in Climate and Health at the Priestley International Centre for Climate, University of Leeds²⁸

There is growing evidence that pregnant women and people are able to appropriately thermoregulate; however, when exposed to extreme heat, there are a number of processes that may occur which could harm the mother or foetus, including a reduction in placental blood flow, dehydration, and an inflammatory response that may trigger preterm birth. There is a lack of substantial evidence regarding the processes that cause heat exposure to harm pregnant women.²⁹ Exposure to high temperatures during pregnancy is associated with an increase in obstetric complications such as gestational diabetes mellitus, gestational hypertension, placental abruption, miscarriage, pre-term birth, stillbirth and maternal mortality.³⁰

Heat exposure has also been linked with adverse neonatal outcomes, including low birth weight, congenital birth defects and sudden infant death syndrome (SIDS).³¹ Pregnant women and people and those in maternity wards may be at higher risk of adverse health outcomes due to overheating.³²

However, little data exist on the impact of extreme heat on the health of both a pregnant woman or person and the development of their foetus. This is due to a combination of difficulties in recruiting and retaining volunteers for clinical trials involving pregnant women and people, and the additional ethical barriers to the development of these trials. As such, more research must be undertaken and shared which assesses the impact of heat on pregnant women and people and the short and long-term consequences to childhood development of exposure to heat in the womb.

Children and Infants

The development of the thermoregulatory system is age dependent, and heat extremes are associated with higher mortality rates in infants, particularly newborns.³³ This is because infants have a lower heat loss capacity relative to adults: their relatively high surface area compared with their overall mass allows them to absorb heat more quickly when air temperature is higher than skin temperature.³⁴

Additionally, infants and young children are unable to behaviourally thermoregulate, e.g. to remove themselves from high heat settings such as a hot car³⁴ or to respond independently to thirst as effectively as adults. As such, hypohydration compromises thermoregulatory function to a greater extent in children compared with adults.³⁶

Very few studies exist on both the acute and long-term impacts of heat on children and infants, with guidance focusing on basic sun care protection. Little is currently understood about how heat during childhood development can have a lasting effect on lifelong health and productivity at working age.

People with pre-existing physical and mental health conditions, people taking some prescription medicines and those that misuse drugs

It is understood that pre-existing health issues such as cardiovascular and respiratory disease, diabetes, obesity, hypertension and kidney disease, as well as a suite of rare diseases such as cystic fibrosis and neurological diseases make people more vulnerable to heat stress. This is because the body's heat loss mechanisms may be compromised, limiting the ability to keep deep body temperature at normal levels, and this puts extra strain on the heart, lungs and kidneys. This is corroborated with an observed rise in hospital admissions during heatwaves for people with these conditions.³⁷

Further complicating the impact of heat on people with pre-existing conditions is that they are more likely to be taking certain medications that also put them at increased risk of being impacted by heat. Some antipsychotics, for example, affect thermoregulation (by reducing blood flow to the skin), increase heat production or impair sweating (such as diuretics, antihypertensives, antihistamines, beta blockers, stimulants and certain drugs for epilepsy and Parkinson's disease).³⁸

Extreme temperatures are associated with a rise in mental ill health. During periods of extreme heat, there are increased hospital attendance or admissions for mental health illnesses, suicide and suicidal behaviour. For each 1°C increase in mean monthly average temperature, rates of suicide rise by between 1% and 2%.³⁹ A study from the British Columbia Center for Disease Control (BCCDC) studying the impacts of the Western heat dome event that seared parts of Canada and the Pacific Northwest in June 2021 found that those with a history of schizophrenia were nearly three times as likely to die during that heatwave than during weeks with an average temperature.⁴⁰ Similarly, epileptic seizures and symptoms associated with multiple sclerosis can be worsened by exposure to extreme heat.^{41,42} The mechanisms driving the interactions between

worsening symptoms and heat are still poorly understood.

There are also increased complications associated with the physiological, behavioural and psychosocial interactions among those who misuse drugs and alcohol. Many commonly prescribed medications, such as general anticholinergics, antidepressants and opioids, and illegal narcotics such as cocaine, might compromise physiological heat loss responses.⁴³

Significant gaps in research remain in these vulnerable groups. Most medications have not been systematically studied in a thermoregulatory context, and no studies have used ecologically valid doses in realistic conditions of heat extremes. Empirical evidence of the exact effect of these medications during extreme heat events is urgently needed.

There is also a lack of information on the relationship between physiological and cognitive functions that drive poor mental health outcomes and increases in successful and unsuccessful attempts to take one's own life during periods of extreme heat.

“The risks to people’s health from climate change are also affected by vulnerability and exposure such as through socio-economic factors leading to health inequalities, the location of healthcare buildings, equitable access to greenspace and levels of existing resilience. Health risks will continue to be distributed inequitably with vulnerable populations and regions differentially affected unless these are considered across all policies to improve resilience to climate change”

UK Climate Change Committee, Progress in adapting to climate change 2023 Report to Parliament, March 2023⁴⁴

2.3 Environmental vulnerability

Workers in increased heat risk environments

Workers who are at additional risk for heat related injuries include:

- those with physically demanding jobs;
- those who operate in particularly hot areas (e.g. exposed to the sun, work close to hot machinery);
- those who need to wear personal protective equipment (PPE);
- new workers who have not adapted to occupational heat stress;
- workers who have had health issues during previous hot periods.⁴⁵

This is because they are less able to adapt their behaviour and environment to support their body's physiological response to heat (e.g. construction workers cannot build housing in cool conditions). Employers have a legal obligation to ensure that temperatures in indoor workplaces must be 'reasonable'. However, while the Health and Safety Executive provides guidance on a minimum temperature for working in the UK, there is currently no equivalent maximum.⁴⁶

Sectors that involve high heat-risk work environments include construction, agriculture, manufacturing, transport, mining, emergency response, service work and professional sport. Wet Bulb Globe Temperature (WBGT) is a commonly used occupational heat stress index to give a more nuanced understanding of how the interaction between temperature and humidity affects productivity. When the 'feels like' temperature, a combination of ambient temperature and humidity, exceeds 26°C, health and productivity during physically intense work, such as in construction and agriculture, are adversely affected.⁴⁷

A significant amount of research has been undertaken in this area by exercise physiologists in collaboration

with other disciplines. The challenge now is for this research to be scaled up into larger studies over extended periods of time, and for the research to inform the development of health and safety guidelines and business practices throughout the UK.

People living in poverty

"The adverse effects associated with extreme temperatures do not affect people and communities equally. Individual sociodemographic factors, including socio-economic status, may modify the effect of heat on health. Additionally, environmental and contextual factors, such as the level of urbanisation, access to green space and neighbourhood deprivation, have been found to modify the relationship between heat and health"

Eric Lavigne et al. Environmental Research, February 2023

People living in poverty are more likely to be living in poor health due to the interaction between material, psychosocial and behavioural disadvantages. They are also likely to have less access to the resources that can aid longer-term lifestyle changes that improve individual heat resilience, e.g. access to adequate nutrition and access to gyms or green spaces for exercise

Data analysis from the 2021 Census estimates that 10.8 million people (20.1%) in England living in private households were living in poverty – a rate similar to both Scotland⁴⁸ and Wales.⁴⁹ Of those 10.8 million, 1.3 million people had a cardiovascular or respiratory condition, representing 2.5% of the population living in private households; 675,000 people (1.2%) had a cardiovascular condition and lived in poverty; and 789,000 people (1.5%) had a respiratory condition and lived in poverty. Around 20.4% of people with

cardiovascular or respiratory conditions lived in poverty; the poverty rate was highest in people with chronic obstructive pulmonary disease (24.4%) and lowest in people who had atrial fibrillation (17.3%).⁵⁰

This is particularly acute for people experiencing homelessness. People experiencing homelessness suffer from worse physical and mental health than the general population: in the *Homeless Health Needs Audit 2022*, 63% of respondents reported having a long-term illness, disability or infirmity, and 82% reported having a mental health diagnosis. All of these factors contribute to much lower heat resilience.

Furthermore, people experiencing homelessness have limited access to the resources required for humans to behaviourally thermoregulate, such as cooling spaces, water and adequate nutrition. When exposed to extreme heat, they are at much higher risk of dehydration, sunburn, heatstroke, and other adverse health effects. Higher incidences of mental illness and substance use can compound those risks.

People living in urban heat islands

An urban heat island (UHI) refers to a localised area that is significantly warmer than its surrounding rural areas due to human activities. While urban areas make up only 7% of total land area in the UK, they account for 83% of the population in England,⁵¹ 83% of the population in Scotland⁵² 67% of the population in Wales⁵³ and 64% of the population in Northern Ireland.⁵⁴

Vulnerability to heatwaves is increasingly exacerbated through the UHI phenomenon, caused by a combination of factors: increased population density, less green space and evaporating soil surfaces, and increased use of impervious materials in the built environment.⁵⁵ Global average daytime temperatures in UHIs during the summer reported at between 2.6°C–4.7°C higher compared with rural areas.⁵⁶

While not unique to UHIs, restrictions in current planning laws and a deprioritisation of greening urban environments and public green spaces are particularly harmful to the people that live in them.

“The integration of additional projections of socio-economic factors, such as indicators of health and inequality from the UK-SSPs, will form an important component of future modelling effort and research”

Katie Jenkins et al, Environmental Research, November 2022



Red Alert: Developing a human-centred National Heat Resilience Strategy



3. Developing an effective *Heat Resilience Strategy*

3.1 How can physiology inform the development of a more human-centred policy approach to heat resilience policy?

It is clear from the breadth of actions required to address heat resilience that stakeholders and governments from across the UK at national and local level will need to be involved to improve climate resilience, particularly for vulnerable populations.⁵⁷ We need a coordinated human-centred *Heat Resilience Strategy* that recognises the role of physiology as part of a multi-disciplinary team setting standards and determining actions to mitigate and adapt to heat. This requires a policy response in the following areas:

- New research to fill current knowledge gaps and accelerate translation into policy and action through the synthesis of existing research.
- Built environment and urban planning that adapts to higher temperatures without requiring increasing use of air conditioning and with greater reliance on sustainable personal cooling systems.
- Work with employers to keep people safe at work.
- Public health education to improve the resilience and knowledge of communities and individuals.
- Early warning systems to ensure the risk is communicated with interventions to protect the most vulnerable.

Research in physiology related to heat

The UK is home to some of the world's cutting-edge physiological research into the impact of heat on human health, wellbeing and productivity. While we have significant knowledge about the effects of heat on the human body, there remain areas of uncertainty that require ongoing research. After identifying where the current knowledge base is lacking, governments across the UK should work with funding organisations to prioritise future heat resilience research accordingly.

In particular, there are significant gaps in our understanding of individual variability and the synergy between physiological and environmental stressors, i.e. the extent to which heat affects individuals based on various intrinsic and extrinsic factors. This includes pregnant women and people, older people, people with mental health disorders, and those with pre-existing health conditions. This report has already highlighted research gaps in these areas, and physiology will be crucial in both explaining epidemiological trends in vulnerable risk groups and helping to design interventions for these groups in response to extreme heat.

In addition, more physiological research needs to be undertaken in areas such as:

- The potential for humans to adapt to chronic heat exposure over longer periods, particularly vulnerable populations.
- The response of cells to heat stress at the molecular and biochemical levels.
- The impact of heat stress on cognitive function and the links between heat and mental ill health.
- Whether heat stress leads to compromised immune systems.
- Long term impact of chronic heat exposure on areas such as the metabolic and cardiovascular systems.
- The interaction between current standards of care in terms of prescription medication and multi-morbidity.
- How different physiological and behavioural vulnerabilities interact with one another in extreme heat environments.

To achieve this, more targeted funding should be made available in this area and a greater diversity of trial participants and objectives must be considered.

It is also vital that there is a platform where researchers, policymakers and industry professionals can share findings, challenges and solutions related to

heat resilience and physiology and co-develop work together; for example, understanding how access to green spaces in urban environments can improve resilience to extreme heat. This should include mechanisms to translate research into policy recommendations, community guidelines and business best practices so that rapid knowledge dissemination is at the heart of the research approach.

Built environment and urban planning

Cities, offices and homes in the UK are largely built for cold seasons. To increase resilience against heat, it is imperative to adapt our built environment. If we adapt correctly based on physiological insight and thermal principles, there won't be a requirement to increase air conditioning.

The current policy environment for heat resilience in the UK is shaped by the Climate Change Act 2008, which sets out a framework to reduce domestic emissions and ensure the UK adapts to climate change. The Act requires the government to produce a UK Climate Change Risk Assessment (CCRA) every five years, followed by a National Adaptation Programme (NAP) to address the risks identified in the CCRA.⁵⁸

The latest CCRA was published in 2022 and identified eight priority areas of risk for the UK, including risks from high temperatures and heatwaves. The third NAP was unveiled in July 2023 and sets out a strategic five-year plan to boost resilience and protect people, homes, businesses and cultural heritage against climate change risks such as flooding, drought and heatwaves.⁵⁹

The NAP includes actions such as:

- Developing a Heat and Health Action Plan to reduce the health impacts of heat exposure.
- Supporting local authorities to develop local heat risk assessments and heat action plans.
- Providing guidance and funding for retrofitting homes and buildings to improve energy efficiency

and thermal comfort. It is of note, however, that current approaches do not focus on an understanding of the physiological determinants of thermal comfort such as the relative importance of shade compared with air flow in achieving thermal comfort. Physiology can better inform what body temperature profile planners should be trying to achieve and how this can vary for different vulnerable populations.

- Ensuring the availability of access to green infrastructure and nature-based solutions to reduce urban heat island effects.
- Developing standards and regulations for sustainable cooling and ventilation systems.
- Supporting innovation and research on low-carbon cooling technologies and heat resilience measures.

The UK government published a UK-wide Heat and Buildings Strategy in October 2021. It sets out how the UK will decarbonise its homes, workplaces and public buildings by 2050. The strategy aims to increase the uptake of low-carbon heating systems such as heat pumps, district heating and hydrogen boilers, as well as improve the energy performance of buildings through insulation, smart controls and energy efficiency measures.⁶⁰ In England, statutory guidance was published on overheating in December 2021, which covers the overheating mitigation requirements of the building regulations as set out in Part O of Schedule 1 to the Building Regulations and in a number of specific building regulations.⁶¹ The Scottish Government published its Heat in Buildings Strategy in October 2021, setting out its programme to deliver agreed climate targets by reducing Scottish dependency on gas and oil for heating homes and other buildings.⁶²

The UK Government's policy on heat resilience is also informed by the advice of independent bodies such as the Committee on Climate Change (CCC) and the Environmental Audit Committee (EAC). The CCC provides regular reports on the progress of adaptation actions and makes recommendations for

future priorities. The EAC conducts inquiries into various aspects of climate change adaptation, such as sustainable cooling solutions, overheating risks and adaptation finance.⁶³

Physiologists can support the definition of human-centred approaches to designing buildings for human comfort during both extreme heat and extreme cold events to support more robust building regulations. This will ultimately save lives, money, NHS resources and contribute to tackling climate change. The designs should embed low energy cost of build and running, and ease of maintaining heat in winter and cool in summer, whilst also being resilient to all extreme weather events.

One such example is the role of personal cooling strategies which do not rely on energy intensive air conditioning systems, which ultimately exacerbate the problem of greenhouse gas-related environmental heating. A future reliance on air conditioning is unsustainable and would further marginalise the communities most vulnerable to the heat. As physiological research demonstrates, a more holistic understanding of the thermal environment from urban planning to building regulations and how they interact with individual physiology support the identification of numerous sustainable opportunities to keep people cooler.⁶⁴

Business

Current policy for how businesses should respond to heat through employment measures and health and safety practices are significantly less stringent and bounded than policies related to work in cold temperatures. This reflects the lack of prioritisation for the UK's response to heat which we have noted in other key areas of policy and would be a key rationale for the development of a coordinated response and prioritisation to heat through a *Heat Resilience Strategy*.

Although there is no legal maximum working temperature set out in law, the law is very clear in the following respect: "During working hours, the temperature in all workplaces inside buildings shall be reasonable". Government guidance defines minimum temperatures in an approved code of practice (ACOP)

- 13°C for strenuous work and 16°C generally. The same ACOP requires temperatures to be reasonably comfortable regardless of whether the work is in a hot or cold environment, and employers are expected to take steps, for example providing green space for employees, to achieve this.⁶⁵

As extreme heat becomes more frequent and longer lasting, there is a gap in current policy which reflects a lack of understanding of how heat physiologically affects different types of workers and how businesses must respond to ensure the continued health and productivity of their workforce.

Public health

"In terms of communication, there is no UK narrative regarding vulnerability to heat, risks of exposure, or the benefits of adaptation. There is a widespread lack of public awareness around the impact of extreme heat, calling for improved public messaging and communication"

Dr Candice Howarth et al, Policy Brief May 2023, Grantham Research Institute on Climate Change and the Environment.⁶⁶

Public attitudes in the UK remain largely ignorant to the harmful consequences of more regular, longer lasting and extreme heat.⁶⁷ This is driven, in part, by a lack of policy prioritisation for preparing for extreme heat that we have discussed earlier in this report. Tailored advice for vulnerable groups exists, but this is not communicated more broadly to the general population.

However, public concerns about climate change and frustration around an individual's ability to mitigate the worst effects of climate change remain. Nearly two-thirds of those surveyed by the Office for National Statistics (63%) reported feeling somewhat or very negative when they thought about the future of the environment. Of those who expressed worry, 90% said they had made some or a lot of changes to their lifestyle.⁶⁸

As significant public health guidance already exists to improve the health and well-being of the population, there is an opportunity to combine mitigation benefits with existing public health guidance and early warning systems. This would combine heat mitigation, for example physically active journeys, and heat adaptation, such as building physical resilience through physical activity and sustainable nutrition advice, in preparation for periods of extreme heat.⁶⁹

There is also the opportunity for the expansion of current early warning systems to give extreme heat events parity of esteem with extreme weather conditions more closely associated with the winter months. The recent Adverse Weather and Health Plan⁷⁰ in England is an important step in the right direction, and a future *Heat Resilience Strategy* must think more broadly about how other areas of policymaking can support a coordinated approach to making the plan as effective and widely communicated as possible.

In support of this, The Physiological Society has previously called for naming heatwaves as part of early warning systems of heat to both raise the profile of extreme heat and its impacts in the eyes of the public and also better coordinate the delivery of responses to extreme heat events.⁷¹ While there are conflicting views on the effectiveness of this approach, the World Meteorological Organization (WMO) has committed to conduct an evaluation of the effectiveness, benefits, challenges and sustainability of existing initiatives to name heatwaves, using the findings to inform any future proposals,⁷² and encourages national meteorological services to adopt a similar approach.

What policy gaps currently exist that a *Heat Resilience Strategy* must address?

This report has highlighted a variety of gaps in the national policy response that should now be addressed:

- **Strengthening the regulatory framework and incentives for improving the energy efficiency and thermal performance of new and existing buildings** and ensuring that building standards and codes reflect the latest evidence and best practices on human-centred heat resilience.⁷³ This includes reforms such as making it easier and cheaper for people to add shutters and passive cooling solutions to where they live, regardless of their housing status.
- **Increasing public awareness and engagement on the risks and benefits of heat resilience countermeasures** and providing clear and consistent guidance and advice on how to cope with heat stress and reduce cooling demand.⁷⁴ The Physiological Society has already called for heatwaves to be named with a view to raising awareness and prompting appropriate behaviour.⁷⁵
- **Supporting the development and deployment of low-carbon and sustainable cooling solutions**, such as passive cooling, natural ventilation, evaporative cooling, phase change materials, solar cooling and district cooling.⁷⁶
- **Enhancing the monitoring and evaluation of the impacts and effectiveness of heat resilience policies and programmes** and ensuring that they are aligned with the UK's climate change adaptation and mitigation goals.⁷⁷
- **Learning from other countries and cities represented in international heat networks about how to build more heat resilient systems and populations** but also to feed our physiological insight into the discussions held within these networks.

- **Expanding physiological research to strengthen the public health preparedness and response as it relates to groups and individuals most vulnerable to extreme heat** including among people facing multiple physiological and or environmental risk factors.
- **Better understanding the intersectional nature of the impact of extreme heat** and population's ability to respond to it.
- **Better understanding the impact of prolonged exposure to extreme heat in a variety of real-world settings** including in urban heat islands, hospitals, workplaces, care settings and public spaces.

Sustainable and accessible ways to keep cool

Mitigating climate change is vital, but inevitable rising temperatures means that identifying sustainable cooling strategies is also important. Strategies at the individual scale that focus on cooling the person instead of the surrounding air can be effectively adopted, even in low-resource settings.



- Electric fans**
- + Can provide effective cooling for young healthy adults up to 42°C in 50% humidity
 - Effectiveness is reduced with low humidity, and in older adults (>65 years), unless accompanied by self-dousing
 - Increases dehydration, but can be offset by drinking an extra glass of water per h



- Self-dousing**
- + Can reduce heat strain and dehydration up to 47°C if dousing is sufficient to keep the skin wet
 - + Can be used during power outages
 - Low compatibility with high clothing coverage



- Foot immersion***
- + Can reduce dehydration and thermal discomfort in hot and humid conditions
 - + Can be used during power outages
 - Risk of slips and falls

* Feet immersed above the ankles in 20°C water



- Wet clothing**
- + Provides high evaporative heat loss without needing to sweat
 - + Can be used during power outages
 - Clothing must be re-soaked roughly every 60 min

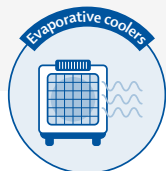


Electric fans can be used below these temperatures irrespective of humidity:

39°C Healthy young adults (aged 18 to 40 years)

38°C Healthy adults (aged over 65)

37°C Over 65s taking anti-cholinergic medication



- Evaporative coolers**
- + Can cool air temperatures in dry conditions
 - Minimal effect in high humidity
 - Risks creating mosquito breeding sites without proper maintenance



- Misting fans**
- + Lowers air temperatures in hot and dry conditions
 - Must be used in well ventilated or outdoor areas otherwise humidity increases offset any benefit
 - Risk of slips and falls



- Ice towels***
- + Can reduce core temperature and cardiovascular strain in conditions up to 45°C
 - Requires access to ice
 - Labour-intensive to prepare

* Crushed ice wrapped in a damp towel applied to the neck and chest



- Cold water ingestion**
- + Can provide internal cooling
 - + Water should be ingested at a temperature that is most palatable (-10°C) to ensure optimal hydration
 - If person has already started sweating, not effective at lowering core temperature

Read the full paper: Jay O, Capon A, Berry P, et al. Reducing the health effects of hot weather and heat extremes: from personal cooling strategies to green cities. *The Lancet* 2021. Published online August 19



“The path to comprehensive solutions requires collaborative, integrated action by politicians, policymakers, epidemiologists, engineers, architects, climate change scientists, behavioural psychologists, healthcare professionals, botanists and physiologists - to provide a fundamental understanding of what humans can tolerate and what needs to be achieved.”

Professor Mike Tipton, Professor of Human and Applied Physiology, University of Portsmouth

Recommendations

Our call for action: a human-centred *Heat Resilience Strategy* in response to rising temperatures.

As the evidence in this report demonstrates, the UK urgently needs to develop a human-centred *Heat Resilience Strategy* that coordinates UK and devolved governments, local authorities, the NHS, research funders and employers to improve resilience in response to higher temperatures. This Strategy must engage with individuals and communities across the country.

We make four recommendations for the UK Government and devolved administrations to develop such a *Heat Resilience Strategy*.

1. Recommendation:

Establish a *Heat Adaptation Research Exchange Taskforce*, chaired by the Cabinet Office working closely with other government departments and devolved administrations. This Taskforce will tackle research gaps and increase the speed of research translation into policy and action.

Intended outcome:

Improved heat resilience by improving our knowledge base through a greater focus and funding on the research gaps identified in this report, particularly around vulnerable populations, and ensuring communities can benefit from the research quickly.

Next steps

- The Taskforce should be ministerially led and should consist of a consortia of funders along with researchers, policymakers and industry. It will be a platform where all those involved can share findings, challenges and solutions related to heat resilience and physiology.
- It will focus efforts on those deemed most vulnerable and where the most significant research gaps remain, including older people, pregnant women and people, people with pre-existing conditions, and those who take prescription medications.
- The Taskforce will (i) direct funding towards resolving research gaps and (ii) improve and accelerate the dissemination of research into policy recommendations, community guidelines, and business best practices.
- It will prioritise the development of greater diversity in clinical trials to ensure the inclusion of vulnerable populations across the life course from foetal development through childhood, pregnancy and older age, and consider the impact of sex-based differences where appropriate.
- It will drive further integration between physiology and other research domains, e.g. Earth sciences, behavioural sciences and measurement tech, to better determine higher -resolution climate responses throughout the UK and effects of other factors such as pollution on human health.

2. Recommendation:

Form a *Human-Centred Climate Adaption Design and Planning Institute* to accelerate the adaptation of the built environment to higher temperatures, with governments across the UK mandating thermally efficient design principles and promoting the use of green infrastructure.

Intended outcome:

The design of buildings and urban spaces will be informed by the physiological response to increased heat and in such a way to support people to adapt to rising temperatures without requiring a huge increase in the reliance on air conditioning.

Next steps

- The new Institute will take a holistic approach in order to improve the application of physiological research into urban planning and built environment strategies. By bringing together physiologists, architects, designers, planners and others, it will consider areas such as building regulations, planning policies, green building standards, financial/regulatory incentives and research.
- Areas of particular focus should include:
 - Enhancing building design and materials for thermal regulation, e.g. using reflective materials, thermoprotective roofing and glass, optimising natural ventilation, and improving insulation.

- Integrating green infrastructure and cooling solutions into buildings (e.g. incorporating green walls/roofs, indoor water features).
- Subsidies and ‘green mortgage’ finance schemes to enable equitable and sustainable retrofitting of existing housing stock through countermeasures including the installation of passive cooling systems and energy efficient cooling systems.
- Increased priority for green spaces in the urban environment, such as the ‘greening’ of roads and public spaces and a greater focus on active transport.*
- Providing greater access to cool zones for the most vulnerable populations in settings where they are most likely to live and work.

*Active transport (or active mobility) includes walking and cycling. These modes of transport can be prioritised and encouraged through a range of government initiatives including urban planning and social prescribing.



3. Recommendation:

Require all employers to develop a physiologically informed and sustainable plan for workers during extreme heat events to protect health, safety, wellbeing and productivity, including introducing statutory guidance on maximum temperatures for different levels of activity and types of Personal Protective Equipment worn.

Intended outcome:

Workers across all sectors of the UK's economy are protected as temperatures increase.

Next steps

- This can be achieved by working with the Health and Safety Executive to update and prioritise occupational responses to extreme heat to take into account temperature, humidity, airflow and pollutions, work/rest scheduling, work equipment and clothing.
- Statutory guidance for a maximum temperature for work must take into consideration humidity, type of work and any protective clothing worn. Where practical, solar load and air movement should also be considered.
- Consideration will have to be given to how to appropriately implement this with employers of different sizes
- In particularly physiologically stressful work roles and settings, working hours will need to be reorganised and reduced during extreme heat in order to maximise productivity and worker wellbeing.
- Facilitating research in workplaces and working environments will allow better understanding of the physiology of extreme heat and resilience countermeasures on humans in real world settings.

4. Recommendation:

Bring together public health professionals from across the UK and devolved governments, local authorities, and charities to deliver a public health campaign and expanded early warning systems focused on supporting vulnerable groups to improve their long term resilience to heat and preparedness for heatwaves.

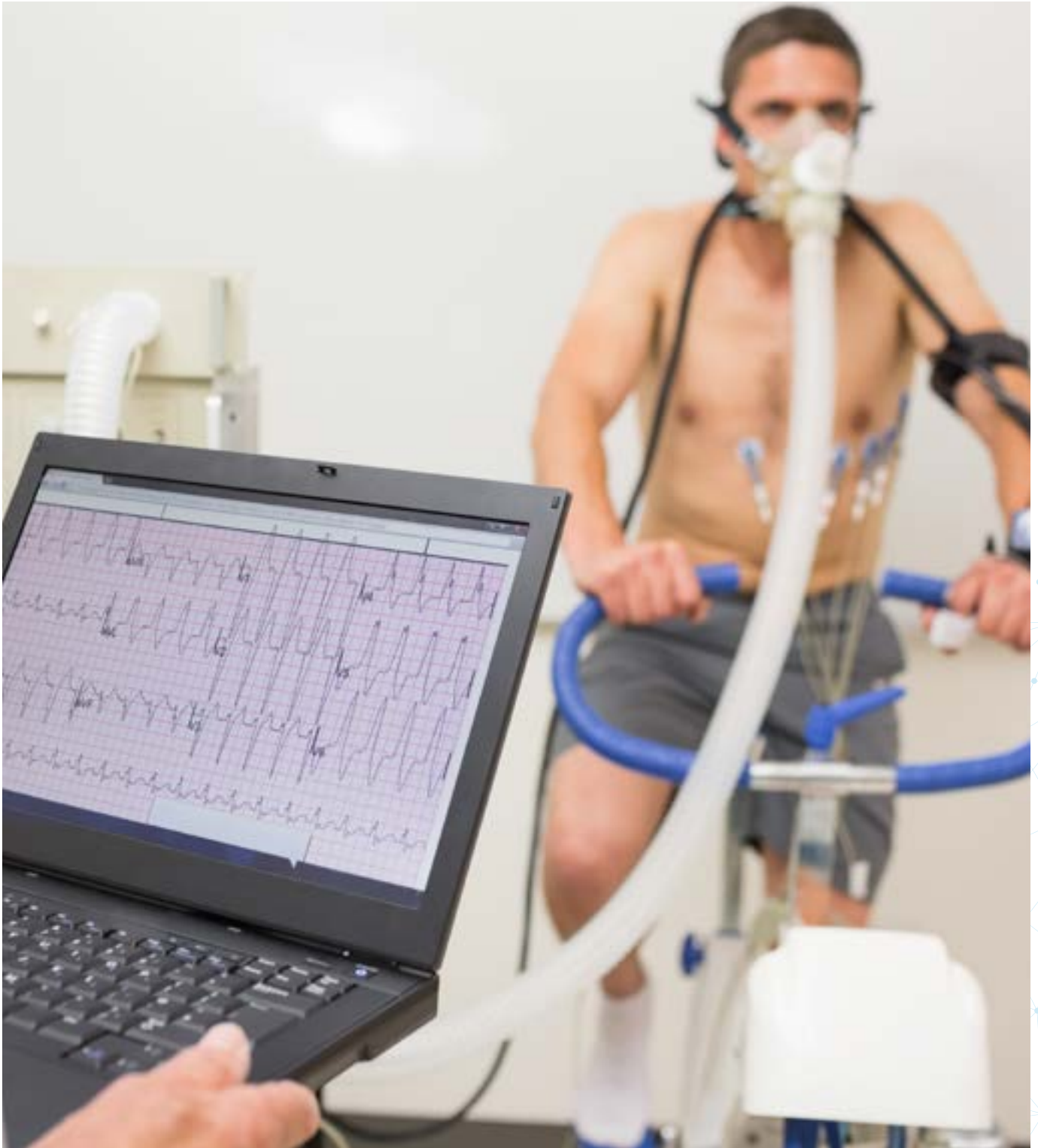
Intended outcome:

Reduced health complications in vulnerable populations due to rising heat by ensuring they have the knowledge and capability to improve long term preparedness, as well as information about when and how they should take action to keep safe.

Next steps

- **Education:** Expand existing public health education around longer-term sustainable behavioural modifications that can improve the body's resilience to extreme heat e.g. accessible education and information on physical activity, nutrition and hydration and personal cooling strategies.
- **Access:** Protect existing sport and physical activity facilities, e.g. pitches, courts, pools and leisure centres, and prioritise the development of new facilities in lower-income communities. Provide support in the form of subsidies to expand access to fee-based health and fitness resources, e.g. gyms, for people in lower socioeconomic groups.

- **Early warning systems:** Build on the UKHSA and Met Office's Heat Health Alert service to develop a comprehensive UK-wide early warning system for extreme heat events that uses public communications such as mass text notifications, online maps to nearest cool zones and heat health emergency facilities that offer physiological advice on avoiding the harmful effects of extreme heat. To raise public awareness of the risks of extreme heat, the Met Office should review the evidence with a view to naming heatwaves in a similar way to other extreme weather events.
- **Action:** Ensure that vulnerable people and communities have access to critical information around direct actions they can take to protect themselves before and during extreme heat events.





Case studies

What examples of initiatives to tackle extreme heat and enable a sustained heat resilience response currently exist within the United Kingdom?

HEATS-HIELD project: Consortia of European research groups including Loughborough University and Wolverhampton University⁷⁸

The HEAT-SHIELD project will create a sustainable inter-sector framework that will promote health as well as work productivity for European citizens in the context of global warming.

The project will produce a series of state-of-the-art innovative outcomes including:

- Appropriate technical and biophysical research-based solutions to be implemented when the ambient temperature poses a health threat or impairs productivity.
- A weather-based warning system with online open access service that anticipates the events that may pose a threat to workers' health.
- Scenario-specific policies and solutions aimed at health promotion and preventing loss of productivity.
- Implementation of the formulated policies and evaluation of their health, economic and social benefits.

Wellcome Trust: research to explore the impact of exposure to rising temperatures during pregnancy⁷⁹

A multidisciplinary team of scientists at the University of Nottingham in collaboration with the University of Leeds have received £2 million Wellcome Trust funding to work on a project to determine how transient exposure to heat stress during early pregnancy affects pregnancy establishment and the long-term health of the child.

This new study aims to identify how short-term exposure to elevated temperatures (typically between 28 and 33°C) during the first two weeks of pregnancy affects embryo development, implantation and adult-offspring health. One of the aims of the study is to identify intervention points to alleviate the effects of extreme heat during early pregnancy.

North Somerset: building resilience to extreme weather and climate change⁸⁰

The climate change adaptation action plan was produced to provide detail on how North Somerset Partnership intends to improve the resilience of services and local communities to the impacts of climate change up to 2050.

Priority actions include:

- Adopting a collaborative approach across North Somerset Partnership to raise awareness and take advantage of national initiatives.
- Adopting a programme to review the maintenance regimes for the clearance of the roadside gullies drainage network.
- Adopting a more coordinated approach to assessing the location of vulnerable people across the district and ensuring that adequate plans are in place for re-housing people if long-term damage is sustained to properties.
- The promotion of measures to improve the sustainability of the existing building stock, to include the promotion of natural ventilation and passive cooling techniques; installation of shutters to reduce likelihood of over-heating; the installation of green roofs and sustainable drainage systems.
- Coordination and implementation of measures in NHS & NSC Heatwave Recovery Plans.

Leeds Teaching Hospitals: dedicated Heatwave Plan⁸¹

The purpose of the Leeds Teaching Hospitals NHS Trust (LTHT) Heatwave Plan is to provide guidance on how to protect patients, public and staff from the impact of a heatwave.

The objectives of the plan are to:

Describe roles and responsibilities of key staff in preparing, alerting and preventing the major avoidable effects on health during a heatwave.

- Describe high-risk factors and groups of people in the event of a heatwave.
- Describe heat-related illnesses and their consequences.
- Provide key messages to staff and patients to prevent heat-related illness and heat-related problems.
- Define how the Met Office Heat-Health Alert service will operate in England from 1 June to 30 September.
- Ensure measures are taken to avoid estate and equipment failure (including computers and other hospital equipment).
- Provide advice on the supply of ice (within infection control restrictions).
- Ensure business continuity arrangements are in place for implementation during extreme heat.
- Link to appropriate websites and resources.
- Provide action cards which are simple to operate and ensure clarity of roles and responsibilities.

Greater London Authority: Climate Risk Map⁸²

A series of London-wide climate risk maps has been produced to analyse climate exposure and vulnerability across Greater London. These maps were produced by Bloomberg Associates in collaboration with the Greater London Authority to help the GLA and other London-based

organisations deliver equitable responses to the impacts of climate change and target resources to support communities at highest risk.

Climate vulnerability relates to people's exposure to climate impacts like flooding or heatwaves, but also to personal and social factors that affect their ability to cope with and respond to extreme events. High climate risk coincides with areas of income and health inequalities. A series of citywide maps overlays key metrics to identify areas within London that are most exposed to climate impacts with high concentrations of vulnerable populations.

The mayor is addressing these climate risks and inequalities through the work of the London Recovery Board, which includes projects and programmes to address climate risks and ensure a green recovery from the pandemic. Ambitious policies in the London Environment Strategy and recently published new London Plan are also addressing London's climate risks.

London City Hall: Cool Spaces⁸³

Cool spaces are indoor spaces where Londoners can find opportunities to shelter from the sun, cool down and rest to take respite on hot days. The spaces are added to the Cool spaces map which goes live from 1 June 2023 until 30 September, in alignment with the heat-health alerting season set out in the UK Health Security Agency's (UKHSA) Adverse Weather and Health Plan. Users can search a map for types of cooling services, and by place name or postcode.

Scotland: Climate Change Adaptation Programme (progress report 2023)⁸⁴

This covers a wide range of topics but includes the following:

The Scottish Government published its Heat in Buildings Strategy in October 2021. Their delivery programmes continue to prioritise 'fabric first' but increasingly deliver a wider range of improvements as part of a 'whole house' approach. Energy efficiency measures, such as external wall insulation, and passive measures, such as ventilation and shading, can improve the resilience of Scotland's buildings to the

increased adverse weather projected as a result of climate change which might cause increased demand for both heating and cooling.

The Scottish Government's review programme set out plans for the publication of revised standards in April 2022; from February 2023, building regulations address overheating in new homes and some other new residential buildings, with further consideration to be given to this topic as part of future review of energy and ventilation standards.

The Green Recovery Statement, published by HES in April 2022, includes the land management of the historic environment as a key principle in helping to building resilient landscapes that are adaptive to climate change.

Joseph Rowntree Foundation research on 'Care provision fit for a future climate: overheating in care settings'⁸⁵

A fifteen-month research study (2016) funded by the Joseph Rowntree Foundation. A socio-technical case study based approach led by Oxford Brookes University in collaboration with University of Manchester and Lancaster University:

- Examined how far existing care homes and other care provision in the UK are fit for a warming climate.
- Considered the preparedness of the care sector (both residential and extra care) with a focus on overheating.

Essex: Green Infrastructure Strategy⁸⁶

A 2020 strategy that champions for high-quality green space and green infrastructure in Essex. The purpose of this strategy is to take a positive approach to enhance, protect and create an inclusive and integrated network of high-quality green infrastructure in Greater Essex. This will help to create a county-wide understanding of green infrastructure, its functions and values, and to identify opportunities for delivering green infrastructure.

Oxford: Green and Blue Space Network⁸⁷

The Oxford Green and Blue Space Network (GBSN) was established in 2013 with the aim of enabling partners to work more collaboratively to improve Oxford's green spaces and blue corridors.

The GBSN is attended by a representative group of agencies and landowners across Oxford. It is chaired by Oxford City Council, and includes a wide range of partners who work to improve the city's green and blue spaces.

Northern Ireland: Belfast Heat Vulnerability Index

In 2022 the Met Office partnered with Belfast City Council and Climate Northern Ireland to create a Heat Vulnerability Index (HVI) for Belfast. The HVI uses metrics on hazard exposure, sensitivity, and adaptive capacity to provide a relative, numerical score for the 60 electoral wards in Belfast. This can be used to determine which parts of the city are at greater risk of extreme heat than others, and to plan mitigation strategies accordingly.

Grantham Institute: Extreme heat preparedness and resilience in the UK

Grantham Institute projects, funded by the LSE and with collaborators including the British Red Cross and Met Office, collected data on national, regional and city-level heatwave responses in the aftermath of the 2022 UK heatwaves. Stakeholders were brought together from the public, private and third sectors to work on improving short-term resilience, to strengthen preparedness and responses to extreme heat events, and to integrate longer-term adaptation action.

They examined experiences, perceptions, decision-making processes and prioritisation of strategies on heat in order to assess the sufficiency of existing policies. Aims included building stakeholder capacity across a multi-sector partnership to develop new evidence, overcome adaptation barriers and integrate responses to heat risk, setting out priorities for policy, research and practice at the local and regional level.

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