Environmental Science and Policy 147 (2023) 57–66

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Heat-health governance in a cool nation: A case study of Scotland

Kai Wan[a,*], Matt Lane[b], Zhiqiang Feng[a,c]

[a] School of Geosciences, University of Edinburgh, Drummond Street, Edinburgh EH8 9XP, UK
[b] Department of Geography, University College London, North-West Wing, Gower Street, London WC1E 6BT, UK
[c] Scottish Centre for Administrative Data Research, School of Geosciences, University of Edinburgh, Drummond Street, Edinburgh EH8 9XP, UK

ARTICLE INFO

Keywords:
Heat
Cold
Health
Climate change
Scotland

ABSTRACT

Under climate change, many parts of the world are warming with increasing frequencies and intensities of heatwaves, bringing heat-health risks to places including those that have a historically temperate or cool climate. These places may have extensive experience in managing cold-health risks, while experience is lacking in dealing with heat-health risks due to their lack of historical exposure to high temperatures. This paper explores this overlooked area of the challenges and opportunities of heat-health governance in cool places using Scotland as a case study. Various important themes of heat-health governance in cool places were identified by the study, including socio-cultural barriers to intervention, vulnerable population overlaps, temporal and geographical scales, and governance arrangements. The study found challenges in managing heat-health risks including a perceived lack of heat-health risks and policy priority as well as unsuitable building stock. Meanwhile, it also identified opportunities for governing cold and heat risks holistically within existing institutional systems and creating co-benefits of improving communication and information dissemination, reducing inequality and improving indoor thermal comfort of both cold and heat as well as providing good quality greenspace. Our findings contribute to the development or improvement of national/regional strategies to manage heat-health risks not only in Scotland but also in other places with a historically cool or temperate climate.

1. Introduction

A recording-breaking heatwave occurred across Europe in summer 2022, which extended north to Scotland with a record-high maximum temperature of 35 °C (Kendon, 2022). Scotland has a cool climate with an annual average temperature of 7 °C between 1961 and 1990 (Met Office, n.d.-a). Whilst being historically cool, there is an increasing heat risk in Scotland under climate change (Undorf et al., 2020).

Considerable evidence shows that high temperatures are associated with adverse health effects, including increased hospitalisation and mortality (Arbuthnott and Hajat, 2017). For example, the record-breaking warm summer in the UK in 2022 resulted in over 3000 excess deaths in England and Wales (ONS, 2022a). Another exceptional heatwave occurred in Europe in the summer of 2003, which led to around 70,000 excess deaths (Robine et al., 2007; García-Herrera et al., 2010). A global review study of 11 papers with a total of 64 locations in six continents found that mortality generally increased by 1–3 % with each degree increase in high temperatures (Hajat and Kosatky, 2010).

Without effective intervention and adaptation, the risk of adverse health effects due to heat could increase substantially through the combined effects of global warming, population ageing and urbanisation (WHO Europe, 2021). Heat-health warning systems (HHWS) with forecasts on high temperatures are useful to alert policy-makers, stakeholders and the public and take preventative actions to avoid adverse health impacts, with the first operational HHWS in Europe established in Lisbon, Portugal in 1999 (Leite et al., 2020). The World Health Organization Regional Office for Europe (WHO Europe, 2008, 2021) published guidance on Heat-Health Action Plans (HHAPs) aiming to support countries and regions in designing, improving and implementing heat-health strategies to prevent adverse heat-health impacts. By 2019, around 20 European countries have implemented national, regional or local HHAPs and/or heat-health warning systems (European Climate and Health Observatory, n.d.).

Although heat-health impacts have been mostly regarded as a risk in hot areas, it may also be a risk, often an invisible one, in areas that have a historically cool or temperate climate, which may be exacerbated under climate change (Brimicombe et al., 2021). Research has found an increase in mortality under high temperatures in cold places such as Scotland (Wan et al., 2022), Sweden (Baccini et al., 2008; Rocklov et al., 2011; Gasparrini et al., 2015), Estonia (Oudin Åström et al., 2016),

* Correspondence to: Drummond St, Edinburgh EH8 9XP, UK.
E-mail address: K.Wan@sms.ed.ac.uk (K. Wan).

https://doi.org/10.1016/j.envsci.2023.05.019
Received 20 December 2022; Received in revised form 31 March 2023; Accepted 26 May 2023
Available online 6 June 2023

Finland (Donaldson et al., 2003; Baccini et al., 2008) and Russia (Revich and Shaposhnikov, 2008). For example, it is estimated that there were 601–750 excess deaths during the exceptionally hot summer in Sweden in 2018 (Astrom et al., 2019).

The threshold temperature above which mortality risk begins to rise has been found to be generally higher in warmer areas, indicating population adaptation (Hajat and Kosatky, 2010; Guo et al., 2014). Therefore, people in cold areas may be more vulnerable and less able to adapt to high temperatures compared to those living in warm areas. This may be due to various factors such as physiological acclimatisation, preventative and protective behaviours, heat-health governance and cooling strategies in housing and planning (Ekamper et al., 2009; Christidis et al., 2010).

With a high focus on cold risks, there is a need to explore the particular need for heat-health strategies in cold countries. For example, while those living in cold and temperate climates may be more vulnerable to extreme heat events, experience in governing and managing cold-health risks may offer transferable knowledge, beneficial to managing heat-health risks. Equally, however, embedded practices focused on cold-weather events may pose barriers to the development of effective heat-health strategies.

This study explores heat-health adaptation and governance using Scotland as a case study. Scotland was chosen because it has a cool climate but is facing higher temperatures under climate change. As a devolved nation of the UK, Scotland is in charge of creating its own policies on the environment, health and social care matters—those that are linked to heat-health strategies under climate change (Scottish Parliament, n.b.). Scotland has been actively taking measures to reduce the impacts of cold weather such as improving energy efficiency by increasing building insulation as well as providing support and benefits. However, to the best of our knowledge, there is currently no dedicated national HHAP in Scotland. Therefore, plans and actions to protect the public health of Scottish residents from avoidable heat-related health impacts are desirable. These features make Scotland an optimal case study to investigate heat-health governance in a historically cool place.

To do this, the study focuses on two key questions: i) what are the key considerations in preventing and managing heat-health risks by policymakers and stakeholders in the health, climate change, environment, and planning sectors; and ii) what are the associated challenges and opportunities.

2. Case study: Scotland

The WHO Europe (2008) recommends individual countries or regions scrutinise their individual context so that HHAPs can be developed or improved accordingly. In this section, the climate and climate change, vulnerability to heat-health risk under climate change, and policies relevant to heat and cold-health risk prevention and reduction in Scotland are introduced, which will provide a context to understand, discuss and interpret the study results.

2.1. Climate and climate change

The annual average daily mean temperature in Scotland is 7 °C between 1961 and 1990 (Fig. 1). It has a cool summer with an average daily maximum temperature of 16 °C in June, July and August, 1961–1990 (Met Office, n.d.-a). However, an increase of 0.9 °C in annual mean temperature has been observed in Scotland in 2011–2020 compared to 1961–1990 (Kendon et al., 2021).

Under climate change, temperatures are projected to continue increasing. The annual mean temperature in Scotland is projected to increase by 1.1 °C under Representative Concentrative Pathway (RCP) 2.6, and 2 °C under RCP6.0 by the 2080 s relative to 1981–2000 (Sniffer, 2021). High-temperature extremes are also projected to be more frequent and intense (Murphy et al., 2019; Undorf et al., 2020).

Although Scotland has a relatively cool climate, anecdotal evidence of heat-related impacts and indoor overheating has been reported (Morgan et al., 2017; Undorf et al., 2020). A recent study using time series data in Scotland in the past 45 years found an increase in the mortality risk of 4 % under the 99th percentile of daily mean temperature compared to the 90th percentile (Wan et al., 2022). These heat risks could be further exacerbated by climate change without effective interventions.

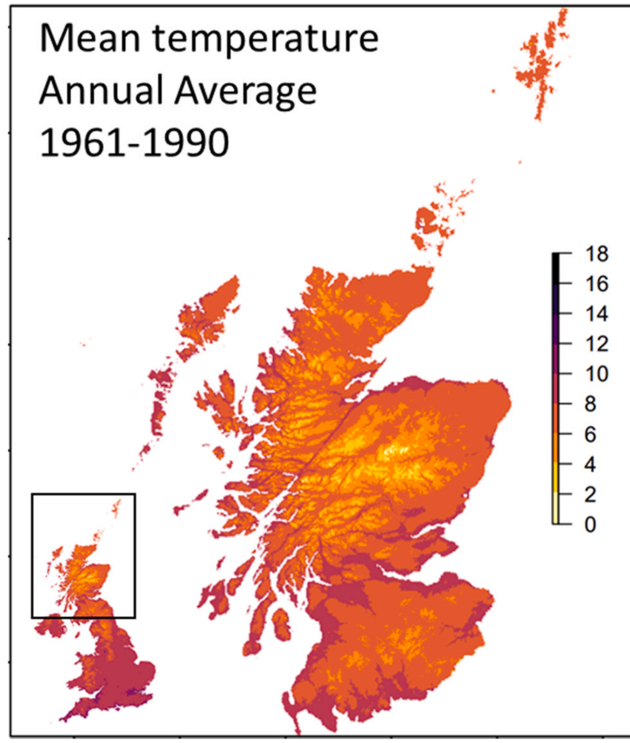

Fig. 1. Annual average daily mean temperature in the UK, 1961–1990. Data obtained from (Met Office et al., 2022).

2.2. Demographic and socioeconomic vulnerability

The mortality rate in Scotland, especially in Glasgow, has been higher than in the rest of the UK and among the highest in Western Europe since the 1950s (McCartney et al., 2012; Schofield et al., 2016; NRS, 2021). This phenomenon persists after the control of socioeconomic deprivation using areal deprivation indices (Walsh et al., 2010; Schofield et al., 2016). Hypotheses of the principal factors leading to the poorer health in Scotland include lagged adverse effects of overcrowding, poor housing conditions, and deindustrialisation such as job loss, skilled labour loss, population relocation and city "redevelopment" policies since the 1950s (Collins and Levitt, 2016; Walsh et al., 2017). These led to weakened and deprived communities and negative health behaviours (e.g. smoking, drinking alcohol and illicit drug taking).

In addition, there is an overall decreasing trend of mortality rate in the UK including Scotland since 1951; however, the improvement in health stalled from 2012 with an increase in mortality rate among the most deprived population (Walsh et al., 2020). This is likely attributed to the austerity policies by the UK Government from 2010 including reduced public spending on services such as local government and healthcare, decreased incomes of the poorest and widening inequality (McCartney et al., 2022).

The proportion of the elderly population in Scotland is projected to continue increasing, with the number of people aged 75 and over projected to increase by 67 % between 2020 and 2045 (NRS, 2022), which is higher than the UK-average increase of 59 % (ONS, 2022b). Population ageing will contribute to increased population vulnerability and challenges in health and social care services.

Whilst, the primary focus of buildings in Scotland has been keeping them warm in winter and increasing energy efficiency with one of the main solutions as improving insulation (Scottish Government, 2018). However, there is some evidence that overheating is more likely to occur in rooms with a higher energy efficiency rating (BEIS, 2021). A study investigated 26 newly built low-energy homes in Scotland and found overheating occurred in 60 % of rooms in July, 2013 and 25 % of rooms for 3–9 months in 2013 (Morgan et al., 2017).

2.3. Policy context related to cold/heat-health risk

As introduced in Section 1, there is currently no dedicated HHAP in Scotland. Therefore, this section will review existing wider climate change adaptation policies that may be relevant to the reduction of heat-health risks. Policies relevant to the management of cold risks are reviewed too, which may be transferable to heat risks and bring opportunities and challenges to heat-health governance.

The provision of climate change adaptation is enforced by law in Scotland through the UK Climate Change Act 2008 and the Climate Change (Scotland) Act 2009. The laws require the publication of a climate change risk assessment (CCRA) by the Committee on Climate Change and the implementation of a national climate change adaptation programme (CCAP) by the government every five years. Climate change adaptation objectives and policies are included in CCAPs, the progress of which is required to be reported annually. Until now, three CCRAs (DEFEA, 2012; UK Government, 2017; CCC, 2021) have been published, each with a national summary for Scotland (DEFRA, 2012; CCC, 2017; Sniffer, 2021). The heat-health risk is identified as a research priority in the 2nd CCRA (ASC, 2016), and one of the most urgent risks that need more action in the 3rd CCRA (Sniffer, 2021).

Improving energy efficiency contribute to reducing fuel poverty, which is another policy target of the Scottish Government. Fuel poverty refers to the challenge of a home being warm long enough, as defined by the Fuel Poverty (Targets, Definition and Strategy) (Scotland) Act 2019, which also sets statutory targets for eradicating fuel poverty in Scotland by 2040. The Scottish Government funds multiple schemes to help people who have difficulties paying fuel bills or keeping homes warm, such as by improving insulation and implementing renewable energy.

Although having no dedicated HHAP in Scotland, the UK Met Office launched an Extreme Heat National Severe Weather Warning service to all nations of the UK including Scotland in June 2021 (Met Office, 2021). This warning is not targeted to indicate the level of health impacts of heatwaves as the heat-health alert in England by the Health Security Agency (formally by Public Health England) (Public Health England, 2022b). Instead, it is to be issued based on all aspects of impact including infrastructure, transport, energy, business as well as health, which has two levels of alert based on medium and high levels of impact (corresponding to amber and red warning respectively) (Met Office, n.d.-b).

An amber warning of extreme heat was issued in a large part of Scotland in July 2022, which activated the operation of the Scottish Government Resilience Division (Scottish Government, 2022). The Resilience Division is responsible for leading emergency planning, response and recovery for the Scottish Government that involves a large variety of organisations such as local authorities, police, fire, health boards and ambulance (Ready Scotland, 2016). Hot weather is one of the severe weathers of which preventative information is provided at Ready Scotland (n.d.), the website maintained by the Resilience Division.

3. Methods

A stakeholder mapping was conducted to identify organisations and individuals who have the potential to influence, either directly or indirectly, policy decisions and the delivery of HHAPs (Chevalier and Buckles, 2019). A snowball approach was adopted in the stakeholder mapping with additional stakeholders recommended by identified stakeholders. The mapping initially focused on Scottish stakeholders, with stakeholders in England added for their close relevancy to this study as suggested by identified stakeholders. For instance, this included stakeholders who had a work or research background in Scotland, or who had collaborations with the Scottish stakeholders. Please see Appendix for the list of identified stakeholder (the interviewees are excluded from Appendix for confidentiality).

This study has undergone research ethics assessment, which was reviewed and approved by the School of GeoSciences, University of Edinburgh. An information sheet was provided to each interviewees giving the study information, their rights and data protection measures. Oral consent was obtained prior to the interviews.

A total of fifty-nine interview invitations were sent out to identified stakeholders in Scotland and England between October 2020 and February 2021. Among the fifty-nine invited stakeholders, nineteen refused the interview and reported a lack of focus or expertise in this topic. Nine stated no capacity, and sixteen did not reply. In the end, fifteen semi-structured interviews were conducted with stakeholders in the health, climate change, environment, and planning sectors in Scotland and England. Two additional written responses were also obtained. The low response rate and high rate of reported lacking expertise among the invited stakeholders partly reflect the situation of a gap in heat-health research and governance in Scotland.

The interviews focused on five themes: 1) socio-cultural barriers to intervention; 2) vulnerable population and communication; 3) heat-health strategy at different temporal and geographical levels; 4) key sectors and leading and collaborative agencies; and 5) governance approach (Fig. 1). The first theme was selected to investigate the particular social and policy context in Scotland contributing to its status of heat-health governance. The following themes were informed by the core elements of a comprehensive HHAP identified by the WHO Europe (2008). Please see the Appendix for the full list of questions. The interviewers were given the information that the context of the interview is Scotland. The questions were primarily designed for the context of Scotland. When interviewing individuals located in England, their experience and perspectives in the Scottish context were specifically asked.

The interviews were audio-recorded upon oral consent from the interviewees and then transcribed for analysis. The interview transcriptions were analysed by thematic analysis (Gray, 2014). The transcriptions were read by one researcher to find themes with patterns and common topics. The questions and themes are not one-to-one corresponded with the answers to one question may be mapped to multiple themes (Appendix). This was because a) the themes are not mutually exclusive; b) interview questions were informed by the literature and asked to interviewees based on their background from the stakeholder analysis, to ensure they were relevant; and c) interviewees were afforded sufficient time to provide their opinions on topics in which they possessed greater knowledge and experience. This approach is beneficial in gaining in-depth information, but has the drawback of potentially straying from the original question and limiting time for other questions. Nevertheless, this approach was adopted because it yielded detailed and useful additional information.

The interviewees were anonymised with abbreviations of their agency or main expertise. Please see the abbreviation and a brief description of their background and expertise in Table 1. Each transcription document was line-numbered. Quotes were indexed with the abbreviation of the interviewee who expressed them, followed by a dash and the starting line number of the quote, placed in square brackets, e.g. [PHE-376]. Sometimes, one or multiple quote indices are given for an argument instead of presenting individual original quotes. It should be noted that the number of quote indices provided should not be extracted to calculate the proportion of the interviewees who support or oppose an argument from the total interviewees or the strength of the argument because not all interviewees were asked the same questions.

Table 1
Interviewee abbreviations, descriptions, the type of organisation and their current location (Scotland or England).

Interviewee	Description	Organisation	Location
CCAR	Climate change adaptation researcher with expertise in adaptation practice and policy	Academic	Scotland
CCHE	Climate change and health epidemiologist and a lead scientist for the UK Climate Change Risk Assessment	Academic	England
CCPM	Climate change programme manager leading projects on behalf of the Scottish Government and local authorities	Third sector	Scotland
CCRA	Climate change risk and adaptation researcher with expertise in disaster risk reduction and risk assessment methods and tools	Academic and third sector	Scotland
EHO	Environment and health official with work experience in both health service and environmental agency	Public sector	Scotland
EHR1	Environment and health researcher with a focus on the health effects of climate change	Public sector	England
EHR2	Environment and health researcher with experience in working in the public health sector in Scotland	Public sector	England
ESS	Environmental social scientist focusing the relationship among people and the natural and built environments, especially adaptation to climate change	Academic	Scotland
HG	Human geographer on urban environment, human-environment interactions and vulnerability mapping	Academic	Scotland
NHSF	Manager at the Facilities Directorate of an NHS board providing support services to buildings with a focus on housing and health	Public sector	Scotland
PHE	Researcher and official at Public Health England (now UK Health Security Agency, UKHSA)	Public sector	England
PHS	Honorary professor of public health and previous director of the public health department of an NHS board.	Public sector	Scotland
SCB	Sustainability capacity building manager who also leads projects on behalf of local authorities	Third sector	Scotland
SP	Spatial planner at an organisation that helps local governments to deliver Scotland's national outcomes	Public sector	Scotland
UM	Urban meteorologist with a research background on the Urban Heat Island effect in Scotland	Academic	England
GP	General practitioner	Public sector	Scotland
SG	Scottish Government	Government	Scotland

Note: GP and SG provided written responses instead of an interview.

The main results and the relationship between Sections 2– 5 in this paper are illustrated in Fig. 2. The climate, demographic, socioeconomic and policy context (Section 2; the outer layer of Fig. 1) shape the design of the interviews and interpretation and discussion of the results. The results are presented in five themes (Section 4; square boxes in Fig. 2) and the results are discussed around the opportunities and challenges in heat-health governance in cool places drawing findings from this study and literature (Section 5; the inner circle in Fig. 2).

There are some limitations of this study. The interviews were conducted in winter 2020/2021 when the COVID19 pandemic was the major social, policy and medical focus. We only received one written response from a medical general practitioner, and we did not interview health and social care practitioners who have close contact with patients and the vulnerable population. However, we did interview professionals from Public Health Scotland, Public Health England, NHS health board, and environmental epidemiologists. In addition, the interviews were conducted in winter, and the temperatures at which the interviews were conducted may affect the perception of the interviewees. For example, the result of the perceived heat-health risk might be slightly different if the interviews were undertaken during a heatwave. Nevertheless, valuable insights could still be obtained from the results and the opportunities and challenges in heat-health governance.

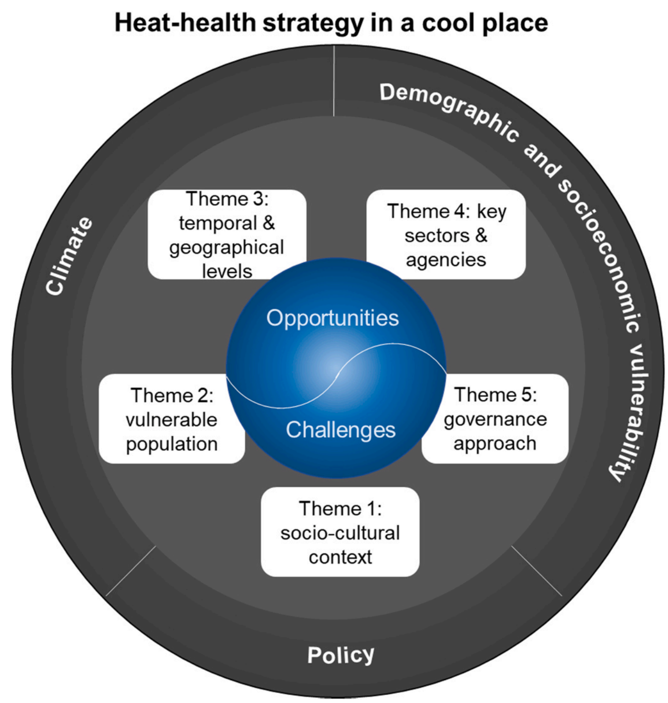

Fig. 2. Schematic graph illustrating the relationship between the climate, demographic, socioeconomic and policy context (Section 2), interview themes (Section 4) and discussion on the opportunities and challenges in heat-health governance (Section 5).

4. Results

In this section, the interviewees' viewpoints and responses are organised and presented in the five themes introduced above.

4.1. *Socio-cultural context to intervention*

Interviewees indicated that the heat-health risks had been perceived to be low and remain low in Scotland at least in the near future because of the cool climate and rare frequency of heatwaves [CCPM-28, ESS-71, PHS-49, PHE-309, SCB-188, EHO-76]. This can be reflected by the culture that Scottish people do not usually take hot summers seriously, as an interviewee indicated "There's a kind of psychology that if it's a warm and sunny day, you have to be outside. If you are not outside in the sunlight, you are wasting all of the sunny days. [ESS-91]".

There was also a perception that increased temperatures may bring about some benefits to Scotland because of the potential for a reduction in cold-related deaths [ESS-73] and increased outdoor activity and time in green space [SG-32].

There was also a lack of evidence on the heat-health in Scotland. An interviewee indicated that the heat-health risk was not flagged as a particularly high risk at the 2nd Climate Change Risk Assessment [CCPM-32], although the urgency level had been elevated in the 3rd CCRA. There was anecdotal evidence of the impact of heat in Scotland, such as the melting of the roof of the Glasgow Science Centre, but in general there was a lack of scientific evidence that heat is a risk to health in Scotland [CCHE-86, CCPM-32, ESS-110].

Preventing heat-health risks under climate change was less of a priority that the government focused on, compared to cold and other meteorological hazards such as flooding [NHS-24, SP-230]. In addition, managing the increasing heat-health risks under climate change was one part of climate change adaptation, which had, however, been overlooked generally compared to mitigation [SP-248, SCB-232, CCPM-58]. For example, a spatial planner shared that “we’re very much about to let’s go and prevent the problem from happening in the first place [SP-248]”.

A climate change and health scientist indicated that compared to other policy areas, public health was responsive and quick. They added “When you decide you need a heatwave plan, you can move things very quickly. So public health is extremely effective. If Scotland wanted to do a heatwave plan, they could set one up in 12 months. [CCHE-97]” Many other European countries developed their heatwave plans in response to the 2003 heatwave.

Therefore, a lack of historical heat exposure, risk and the evidence around it led to a low policy priority and hence a lack of HHAP in Scotland.

4.2. Vulnerable population groups

As discussed in Section 1, some people may be more susceptible to adverse effects from high temperatures making them more vulnerable to heat-related health risks. An official at the PHE (now UKHSA) expressed that vulnerabilities included physiological vulnerability affected by age and underlying comorbidities, contextual vulnerabilities due to place and space such as urban and rural, floor level and building elevation, social vulnerabilities such as from social isolation, and economic vulnerabilities such as poverty and deprivation [PHE-90].

A spatial planner suggested that the definition and selection of vulnerability indicators or indices should depend on the objectives of actions [SP-154]. When communicating the key health risks, the PHE generally pulled out individual factors that increase vulnerability [PHE-101]. This could inform individual sectors and the public in targeting those who may be more vulnerable and hence provide targeted services.

Some stakeholders expressed that poverty is a significant factor underlying vulnerability regardless of the type of risk, and hence should be a primary focus of intervention [NHSF-262, EHO-294]. An environmental health official stated, "from what I understand, I think that if you looked at the determinants of ill-health and health vulnerability, we knew enough about how they relate to poverty…Can we address the causes of poverty? Which, in turn, will reduce the vulnerability through these things. [EHO-294]".

In terms of planning, the spatial planner suggested that all these vulnerabilities should be assessed together for a composite picture because “everything within a place is such an interrelated set of equations [SP-156]”. They expressed that it was unlikely to have an impact focusing on one aspect in isolation. This also links to the preference for a holistic approach to be discussed in Section 4.5.

When attempting to identify and monitor the vulnerable population, a climate change risk and adaptation scientist explained that there was a tension between developing a customised heat-health vulnerability index and maintaining efficiency by using a more general index or dataset that is easier to manage and maintain over time [CCRA-271]. They added that the decision was largely based on practicability – “it was always a trade-off between what we needed to deliver and getting the most available data. It wasn’t always the best quality data. It was kind of what we even have [CCRA-271].”

The method on effective information dissemination and service provision to the vulnerable groups requires careful design. The interviewees recommended that it is crucial that those who are in close contact with the vulnerable population, such as nurses and professionals at care homes and hospitals are engaged in the plan, receive early warnings, are able to interpret the alerts and deliver services to reduce the heat-health risk of the vulnerable populations [HG-363, EHR2–254]. Local knowledge and connection were also suggested to be valuable. For example, an interviewee shared that they discovered that the person who held the most trust among the local population was a priest rather than the government or scientists during a flood risk research in Aberdeenshire [ESS-383]. Therefore, it is both a challenge and opportunity to identify and provide targeted information and services to vulnerable population.

4.3. Temporal and geographical levels

Strategies to prevent and reduce heat-health risks are needed to be more prepared for the increasing temperatures under climate change, at least some point in the future, agreed by many interviewees [HG-300, CCHE-93, EHO-95]. Scottish people may be more vulnerable to heat because buildings, public transport, and people’s behaviours are not adapted to heat. For example, an environmental social scientist said, “If you look at the tropics, places like Taiwan and the south of Japan … coping with heat is not new. People have got strategies for not going out in the middle of the day. And in Japan, they sprinkle water on the pavements and people use strategic greenery and things like that. We don’t have that at all in Scotland. our buildings and public transport are not designed for hot weather. [ESS-164]”.

It is important to have a long-term plan in addition to only relying on short-term responses to alerts [EHR2–144, PHE-376]. A climate change and health epidemiologist indicated, “If you just focus on weather-based alerts, you’re missing 1/3 of the picture [CCHE-37].” Long-term awareness raising is also needed because “you have a few years without heatwaves, it doesn’t mean it’s not coming at its some later time [EHR1–396]”. Therefore, other long-term planning and strategies such as behaviour change, modification of the built environment and building regulations are crucial to mitigate heat risks [CCHE-36].

Only having a national plan is insufficient in protecting the public from heat impacts, the implementation and delivery of preventative information and actions on regional and local levels, particularly to the vulnerable population is vital for the plan to be effective. Plans and actions on national, city and community levels are all required [NHS-177]. When introducing a new national plan, the National Planning Framework is carefully referred to [IS-293]. On the regional level, Joint Boards between the health service and local authorities are formed, the main focus of which is on health and social care, but it can stray into housing and neighbourhood planning [NHSF-199]. It is the responsibility of local authority officials to translate and establish national and regional plans into something useful and practical for the city or local scale [CCRA-66].

Empowering communities instead of just imposing the plans on them is crucial to making effective plans [SCB-121]. As an interviewee indicated, “If something just comes from the SG, and people think it’s alien, then they will fight against it [PHS-177].” Community and neighbourhood support is also crucial in promoting the health of local people. An interviewee gave an example by relating to the situation during the lockdown due to the COVID19 pandemic, "the local authority and the NHS were just so pushed or not able to actually check that people were OK, so people just got on and took care of themselves [SCB-408]". For example, local communities and neighbourhoods took action to help each other such as checking on the elderly and delivering groceries. A similar situation may happen during prolonged heatwaves and hence it is important to make use of community knowledge and empower local communities [SCB-408].

4.4. Key sectors, leading agencies and collaborations

Designing and delivering a heat-health strategy involves a wide range of organisations and professionals in different sectors, e.g. meteorological and climate services, health and social care, and the built and natural environment [CCPM-183]. Therefore, collaboration and joint working across the sectors are essential in taking integrated preparedness and response actions to heatwaves.

The Met Office provides weather forecasts and the health service sector was perceived by multiple stakeholders that should be the leading agency in heat-health strategy [EHO-143, EHR2–251, CCPM-181]. As a climate change project manager expressed, "it should be Public Health Scotland that takes a lead on it. I think that would be the equivalent body has taken the lead in England, so it seems a natural fit [CCPM-181]". Perceived key roles of the health service sector include determining the trigger points of a heat-health alert, translating weather forecasts and alerts into health risks and targeting specific vulnerable populations and regions [EHO-159, CCPM-170].

Scottish Environmental Protection Agency (SEPA) is Scotland's national flood forecasting, warning and strategic risk management authority. Therefore, a stakeholder expressed that SEPA could contribute to a heat-health strategy with the existing framework, collaboration and experience in flood risk management [EHO-142]. Environmental consultancies such as Sniffer could play an advisory role in the development of the plan and promote partnerships among different sectors [CCPM-199].

Due to a lack of regulation on preventing indoor overheating, some of the newly built buildings such as hospitals and schools face indoor overheating conditions and are unfit for extreme temperatures in the future [EHR1–259]. In addition to indoor overheating, an interviewee indicated concerns that highly insulated and airtight buildings may lack air circulation and fresh air exchange from the outside, leading to the building up of dampness and mould and negative health impacts [EHR1–243]. In order to avoid indoor overheating and imbed the cooling needs of buildings, an update of the building regulation was needed [EHR1–264].

Land use and the built and natural environments are also crucial sectors, with green and blue spaces providing natural shading and cooling during high temperatures and multiple co-benefits such as promoting physical and mental health, increasing runoff absorption and mitigating flooding [SCB-116]. Green space should be carefully designed so that people feel safe there, has a sense of ownership and are willing to spend time and make use of it [SP-202, ESS-289].

4.5. Governance approach

A preference for taking the climate change risks and resilience of a place or organisation holistically was expressed by many interviewees [SP-71, CBM-207, CCPM-8, CCRA-439, SCB-207]. A heat-health strategy can be integrated into existing policy priorities and plans, such as fuel poverty and health inequality [SG-4, CCRA-185, ESS-189, SP-192&303]. Some interviewees recommended looking at a community or a place in its full sense and considering what its challenges and opportunities are, including physical (e.g. overheating, abandoned buildings and traffic) and social aspects (e.g. drug problems and social cohesion) [CCPM-84, SG-17].

One advantage of this approach is increasing awareness of heat-health risks using the traction of existing focus and priorities. A climate change resilience researcher gave an example, "If you combine the two [heat and cold plans], then you're also preparing people for heat, even if they're more interested in the cold [CCRA-189]." Another crucial importance of taking a holistic view is to minimise the risk of maladaptation, e.g. by considering both keeping homes warm through insulation as well as avoiding indoor overheating and air pollution [PHE-266].

When designing, delivering and evaluating plans and services, in addition to quantitative data and statistics, it is also crucial that people's lived experience is taken into account, especially those who are already disadvantaged— "How are they being affected by overheating risk and how is that being really fed into evidence base? [CCPM-216]", suggested by a climate change programme manager. An environmental social scientist also emphasised the value of qualitative evidence, e.g. people's narratives and stories, but the government and the public health departments preferred "medical, quantitative, usually economic data because they need to justify the decisions that they're making [ESS-413]".

A spatial planner confirmed that the planning performance framework, the assessment and evaluation in planning done by Scottish councils, is mostly quantitative, e.g. "how many planning applications have you processed? How up-to-date is your local development plan? [SP-121]" They said that "the qualitative aspect about what is the quality of the place you're shaping and what impact is it having on health is not being asked at the moment [SP-126]" because it is difficult to present and compare as quantitative information. However, they expressed that there is a desire to include more qualitative measures in the planning performance assessments to ensure the decisions are the best for the health and wellbeing of the communities.

5. Discussion

The interview results provide insights into the challenges and opportunities of heat-health governance in a nation with a cool or temperate climate, which will be the focus of the discussion in this section (Fig. 1). The challenges and opportunities are not static; instead, they can be transformed into each other, which will be discussed in more detail below. The design of the inner circle of Fig. 1 is inspired by YinYang, a Chinese philosophical concept describing opposite but interconnected forces (Wang, 2012).

The results of Theme 1 found that due to being historically relatively cool in Scotland, there has been a favour of warm sunny days and a lack of perceived heat-health risks. Similar findings of feeling positive about warm or even hot weather were also found in England, although it was generally agreed that temperatures above 26 °C were "too hot" among the study participants of Williams et al. (2019). This may bring challenges in managing heat-health risks and taking planned preventive measures as people also do not usually perceive themselves as being vulnerable or at risk of heat effects (Wolf et al., 2010a; Williams et al., 2019). For example, the elderly have been identified as being vulnerable to heat-health risks, however, previous studies found the elderly in the UK tend not to consider themselves either old or at risk of heat effects (Abrahamson et al., 2008; Wolf et al., 2010b; Ratwatte et al., 2022).

This links to Theme 2 of this study on engaging the vulnerable population. The phenomenon that people tend to perceive themselves as not being affected by heat links to the Third Person Effect in media studies. It describes the situation where an individual perceives themselves as less influenced by persuasive information than others (Davison, 1983). Therefore, one strategy to communicate heat warnings and preventative actions can be framing the advice as helping their vulnerable relatives and neighbours (Roberts, 2022). This is in line with previous research results that social support from peers, e.g. friends and community members is a valuable mechanism for facilitating the elderly during heatwaves (Sampson et al., 2013).

However, the effect of social networks on reducing the vulnerability to heatwaves of the elderly is also complex and affected by their social contacts' perception of heat risks, knowledge on coping and preventive measures as well as perceptions of personal independence and resilience (Wolf et al., 2010b). This highlights the importance of a whole system approach involving the government, health and social care sector and communities at multiple geographical levels, as presented in Theme 3.

The results in Theme 4 show that there are concerns of indoor overheating, especially in new buildings in Scotland. The buildings in Scotland have been primarily designed to reduce heat loss by enhancing airtightness and increasing insulation, which may increase the risk of insufficient ventilation and overheating (Gupta and Kapsali, 2016; Tink et al., 2018). A study found that overheating occurred in 20 of out 26 newly built low-energy homes monitored in Scotland, some of which experienced overheating in all seasons (Morgan et al., 2015). The health risk of overheating has widely been found to be higher for flats in high-rise residential buildings due to reduced conductive heat loss and ventilation opening, lack of shading, additional solar gain for top-floor flats and limited garden access to escape from indoor heat (Lomas and Kane, 2013; Baborska-Narożny et al., 2017).

Building designs are crucial for preventing overheating. The effect of insulation on overheating is mixed, which is by other factors such as insulation type, room orientation and occupant behaviour (Porritt et al., 2012). External wall insulation and roof insulation can mitigate overheating by reducing solar gain (Mavrogianni et al., 2017). On the contrary, internal insulation may contribute to overheating by prohibiting heat dissipation when the external temperature is lower than the internal, or trapping the heat generated internally (Fosas et al., 2018; Fosas et al., 2018). Nevertheless, studies have demonstrated that this can be mitigated through closing blinds during the day and opening windows at night and therefore improved energy efficiency and thermal comfort can be achieved in both winter and summer with proper building design, operation and occupant behaviour (Crump et al., 2009; Tink et al., 2018).

In addition to building design, practicality of mitigation measures and occupant behaviours are crucial in influencing external and internal heat gain as well as ventilation (Jenkins et al., 2009; Baborska-Narożny et al., 2017). Occupants may be reluctant to open windows due to concerns about security, noise or air pollution (Crump et al., 2009; Morgan et al., 2015). Various factors can affect the effectiveness of mechanical ventilation and cooling, such as occupants' insufficient understanding of the system, worry about energy expenses and noise, particularly using a boost mode at night during heatwaves (Dengel and Swainson, 2012; Gupta and Kapsali, 2016). These practicality issues should be considered in building design (Scottish Government, 2023). For example, secure noise attenuating vents could be considered when security and noise are concerns (Tink et al., 2018).

Overheating in care settings, hospitals, communal establishments and schools are of particular concern because the occupants often have reduced mobility or control over adjustments to maintain thermal comfort, which also links to Theme 2. Mitigating overheating in these settings requires more than good building design, but also a high level of awareness, knowledge, care, and management among those responsible for the well-being of occupants, including care providers, teachers, and managers (Gupta et al., 2017; Sinclair, 2018; Ibbetson et al., 2021).

The use of air-conditioning induces extra costs and energy use, which is contradictory to climate change mitigation and may lead to the worsening of fuel poverty, whereas caused by the need of indoor cooling rather than heating (Peacock et al., 2010; Thomson et al., 2019). Currently, only around 1–3 % of homes in the UK have air conditioning (McLachlan et al., 2016). Therefore, passive measures for mitigating overheating should be prioritised, with active measures like air-conditioning only considered when passive measures are not sufficient, as suggested by the latest Scottish Building Standards (Scottish Government, 2023).

Compared to the predominant focus on keeping the indoor environment warm in cold weather, outdoor environments play a crucial role in modifying heat-health impacts (Theme 4). Greenspace is highly effective in providing shade from solar radiation and ambient cooling, which can extend beyond the area of the greenspace by modifying the local climate and hence alleviating the Urban Heat Island effect (Santamouris, 2015; Vaz Monteiro et al., 2016). One of the pieces of advice for staying safe in hot weather provided by Public Health England (2022a) is to walk in shade. There may be some concern about the increased cold stress and energy demand for heating due to the cooling effect of greenspace in winter (Mavrogianni et al., 2009). This trade-off depends on various factors such as the land cover type, the type, location and coverage of vegetation as well as global warming levels; whereas with careful design, the benefits of greenspace on reduced heat stress are likely to outweigh the effect on cold stress (Macintyre et al., 2021; Rahman et al., 2022). There is also the need to highlight the value of greenspace to good health by promoting mental health and healthy behaviours (Mavrogianni et al., 2009; Murage et al., 2020). In addition to the quantity of greenspace, the quality such as tranquillity, greenness and perceived safety is also influential in its health benefits (Baka and Mabon, 2020).

As presented in Theme 5, a holistic approach to an HHAP that targets and deals with key risk factors of a place together, such as weather- and environment-related hazards including cold, heat and flood and other social challenges such as fuel poverty and health inequality is generally preferred by the stakeholders. Integrating heat-health governance with other existing policies may create opportunities in increasing the focus on heat using the traction of the current public and policy focus (Theme 5), as well as making use of existing institutional frameworks and collaborations (Theme 4).

One opportunity for holistic governance is to extend the concept of fuel poverty to both cold and heat (Theme 5). As energy prices soar, communal warm spaces have been developed to keep people warm, particularly for those who cannot afford heating bills. For example, Bristol City Council is planning “welcoming places" which provide warmth as well as food, benefits advice and educational support (Roig, 2022). Similarly, public cool places are desirable too, as Public Health England (2022a) suggested the public considers visiting cool public buildings such as places of worship, local libraries or supermarkets as a way to cool in hot weather.

Holistic governance of cold and heat risks is in line with the practice in Scotland where hot weather is dealt with as one of the adverse weathers by the Scottish Government Resilience Division, along with cold, snow and ice, storms and winds, and rain and flooding (Section 2.3). It also resonates with the movement by the UK Health Security Agency to merge the current separate Cold Weather Plan and Heatwave Plan for England into a single Adverse Weather and Health Plan integrating guidance on cold and hot weather, drought and flooding (Oliver and Ford, 2022; Oliver, Ford, 2022).

6. Conclusions

This study found that the cool climate in Scotland poses both challenges and opportunities in managing heat-health risks. Challenges include a lack of policy priority due to a perceived lack of heat-health risk and evidence, the difficulties in reaching the vulnerable population and the potential conflict between keeping homes warm by improving insulation and indoor overheating.

Nonetheless, challenges can also be transformed into opportunities, as demonstrated by the preference of stakeholders for a holistic governance approach that combines heat-health governance with other policy priorities such as cold, fuel poverty, and health inequality. This approach enables heat-health actions to gain traction and make use of the existing institutional support. Additionally, common information dissemination and service provision methods can be utilised to mitigate both cold and heat risks.

There is an opportunity to enhance the thermal comfort of homes in relation to both cold and heat through effective building design and occupant behaviour, reflected in the latest Scottish Building Standards. Greenspace also plays a crucial role in mitigating heat risks, which requires careful design to promote its health benefits.

Indeed, and in a more conceptual sense, it is perhaps productive to move away from a hot-cold binary and to instead think about ‘unstable temperature’ governance, which covers both hot and cold at the same time. As the climate continues warming, rather than focusing on the external, and thus uncontrollable factor (the temperature), it is also crucial to focus on adaptation and the underlying vulnerabilities which would offer a more tangible framework for structuring the governance of temperature-related health concerns in populations.

CRediT authorship contribution statement

Kai Wan: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing – original draft, Visualization. **Matt Lane:** Writing - Conceptualization, Methodology, Writing – review & editing, Supervision. **Zhiqiang Feng:** Writing - Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of Competing Interest

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

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2023.05.019.

References

Abrahamson, V., Wolf, J., Lorenzoni, I., Fenn, B., Kovats, S., Wilkinson, P., Adger, W.N., Raine, R., 2008. Perceptions of heatwave risks to health: interview-based study of older people in London and Norwich, UK. J. Public Health 31 (1), 119–126. https://doi.org/10.1093/pubmed/fdn102.

Arbuthnott, K.G., Hajat, S., 2017. The health effects of hotter summers and heat waves in the population of the United Kingdom: a review of the evidence. Environ. Health 16, 1–13. https://doi.org/10.1186/s12940-017-0322-5.

ASC, 2016. UK Climate Change Risk Assessment 2017 Evidence Report – Summary for Scotland. Adaptation Sub-Committee of the Committee on Climate Change. London. Available online: ⟨https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Scotland-National-Summary.pdf⟩ (Accessed 29 October 2021).

Astrom, C., Bjelkmar, P., Forsberg, B., 2019. Attributing summer mortality to heat during 2018 heatwave in Sweden. Environ. Epidemiol. 3, 16–17. https://doi.org/10.1097/01.EE9.0000605788.56297.b5.

Baborska-Narożny, M., Stevenson, F., Grudzińska, M., 2017. Overheating in retrofitted flats: occupant practices, learning and interventions. Build. Res. Inf. 45 (1–2), 40–59. https://doi.org/10.1080/09613218.2016.1226671.

Baccini, M., Biggeri, A., Accetta, G., Kosatsky, T., Katsouyanni, K., Analitis, A., Anderson, H.R., Bisanti, L., D'Ippoliti, D., Danova, J., Forsberg, B., Medina, S., Paldy, A., Rabczenko, D., Schindler, C., Michelozzi, P., 2008. Heat effects on mortality in 15 European cities. Epidemiology 19 (5), 711–719. https://doi.org/10.1097/EDE.0b013e318176bfcd.

Baka, A. & Mabon, L., 2020. Assessing equality in neighbourhood availability of quality greenspace in Glasgow, Scotland, United Kingdom. Center for Open Science. Available online: ⟨https://EconPapers.repec.org/RePEc:osf:socarx:d9jeh⟩ (Accessed).

BEIS, 2021. Thermal Comfort, Damp and Ventilation. Building Research Establishment and Loughborough University for the Department of Business Energy and Industrial Strategy. Available online: ⟨https://www.gov.uk/government/publications/energy-follow-up-survey-efus-2017-reports⟩ (Accessed 14 September 2021).

Brimicombe, C., Porter, J.J., Di Napoli, C., Pappenberger, F., Cornforth, R., Petty, C., Cloke, H.L., 2021. Heatwaves: an invisible risk in UK policy and research. Environ. Sci. Policy 116, 1–7. https://doi.org/10.1016/j.envsci.2020.10.021.

CCC, 2017. UK Climate Change Risk Assessment 2017 Evidence Report – Summary for Scotland. Committee on Climate Change. Available online: ⟨https://www.theccc.org.uk/uk-climate-change-risk-assessment-2017/national-summaries/scotland/⟩ (Accessed 08 March 2022).

CCC, 2021. Independent Assessment of UK Climate Risk: Advice to Government For the UK's third Climate Change Risk Assessment (CCRA3). Committee on Climate Change. Available online: ⟨https://www.theccc.org.uk/publication/independent-assessment-of-uk-climate-risk/⟩ (Accessed 08 March 2022).

Chevalier, J.M. & Buckles, D.J., 2019. Chapter 11 Stakeholder basics, in Participatory Action Research: Theory and Methods for Engaged Inquiry, 2 edition. Routledge.

Christidis, N., Donaldson, G.C., Stott, P.A., 2010. Causes for the recent changes in cold- and heat-related mortality in England and Wales. Clim. Change 102 (3–4), 539–553. https://doi.org/10.1007/s10584-009-9774-0.

Collins, C., Levitt, I., 2016. The 'modernisation' of Scotland and its impact on Glasgow, 1955–1979: 'unwanted side effects' and vulnerabilities. Scott. Aff. 25 (3), 294–316. https://doi.org/10.3366/scot.2016.0137 info:doi/10.3366/scot.2016.0137.

Crump, D., Dengel, A. & Swainson, M., 2009. Indoor air quality in highly energy efficient homes – a review. NHBC Foundation. Available online: ⟨https://www.nhbcfoundation.org/wp-content/uploads/2016/05/NF18-Indoor-air-quality-in-highly-energy-efficient-homes.pdf⟩ (Accessed 21 July 2022).

Davison, W.P., 1983. The third-person effect in communication. Public Opin. Q. 47 (1), 1. https://doi.org/10.1086/268763.

DEFEA, 2012. UK Climate Change Risk Assessment: Government Report. Department for Environment, Food & Rural Affairs, UK Government. Available online: ⟨https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-government-report⟩ (Accessed 08 March 2022).

DEFRA , 2012. A climate change risk assessment for Scotland. Available online: ⟨http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15747#RelatedDocuments⟩ (Accessed 16 April 2021).

Dengel, A. & Swainson, M., 2012. Overheating in new homes: a review of the evidence. NHBC Foundation. Available online: ⟨https://www.zerocarbonhub.org/sites/default/files/resources/reports/Overheating_in_New_Homes-A_review_of_the_evidence_NF46.pdf⟩ (Accessed 02 November 2021).

Donaldson, G.C., Keatinge, W.R., Näyhä, S., 2003. Changes in summer temperature and heat-related mortality since 1971 in North Carolina, South Finland, and Southeast England. Environ. Res. 91 (1), 1–7. https://doi.org/10.1016/s0013-9351(02)00002-6.

Ekamper, P., van Poppel, F., van Duin, C., Garssen, J., 2009. 150 Years of temperature-related excess mortality in the Netherlands. Demogr. Res. 21, 385–425. https://doi.org/10.4054/DemRes.2009.21.14.

European Climate and Health Observatory (n.d.) National heat-health warning systems and action plans, n.d. Available online: ⟨https://climate-adapt.eea.europa.eu/observatory/evidence/national-and-sub-national-warning-systems⟩ (Accessed 07 December 2021).

Fosas, D., Coley, D.A., Natarajan, S., Herrera, M., Fosas de Pando, M., Ramallo-Gonzalez, A., 2018. Mitigation versus adaptation: Does insulating dwellings increase overheating risk? Build. Environ. 143, 740–759. https://doi.org/10.1016/j.buildenv.2018.07.033.

García-Herrera, R., Díaz, J., Trigo, R.M., Luterbacher, J., Fischer, E.M., 2010. A review of the European summer heat wave of 2003. Crit. Rev. Environ. Sci. Technol. 40 (4), 267–306. https://doi.org/10.1080/10643380802238137.

Gasparrini, A., Guo, Y.M., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., Tobias, A., Tong, S.L., Rocklov, J., Forsberg, B., Leone, M., De Sario, M., Bell, M.L., Guo, Y.L.L., Wu, C.F., Kan, H., Yi, S.M., Coelho, M., Saldiva, P.H.N., Honda, Y., Kim, H., Armstrong, B., 2015. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet 386 (9991), 369–375. https://doi.org/10.1016/s0140-6736(14)62114-0.

Gray, D.E., 2014. Doing research in the real world, Third edition. Los Angeles, California, US: SAGE.

Guo, Y.M., Gasparrini, A., Armstrong, B., Li, S.S., Tawatsupa, B., Tobias, A., Lavigne, E., Coelho, M., Leone, M., Pan, X.C., Tong, S.L., Tian, L.W., Kim, H., Hashizume, M., Honda, Y., Guo, Y.L.L., Wu, C.F., Punnasiri, K., Yi, S.M., Michelozzi, P., Saldiva, P.H.N., Williams, G., 2014. Global variation in the effects of ambient temperature on mortality a systematic evaluation. Epidemiology 25 (6), 781–789. https://doi.org/10.1097/ede.0000000000000165.

Gupta, R., Kapsali, M., 2016. Empirical assessment of indoor air quality and overheating in low-carbon social housing dwellings in England, UK. Adv. Build. Energy Res. 10 (1), 46–68. https://doi.org/10.1080/17512549.2015.1014843.

Gupta, R., Barnfield, L., Gregg, M., 2017. Overheating in care settings: magnitude, causes, preparedness and remedies. Build. Res. Inf. 45 (1–2), 83–101. https://doi.org/10.1080/09613218.2016.1227923.

Hajat, S., Kosatky, T., 2010. Heat-related mortality: a review and exploration of heterogeneity. J. Epidemiol. Community Health 64 (9), 753–760. https://doi.org/10.1136/jech.2009.087999.

Ibbetson, A., Milojevic, A., Mavrogianni, A., Oikonomou, E., Jain, N., Tsoulou, I., Petrou, G., Gupta, R., Davies, M., Wilkinson, P., 2021. Mortality benefit of building adaptations to protect care home residents against heat risks in the context of uncertainty over loss of life expectancy from heat. Clim. Risk Manag. 32, 100307 https://doi.org/10.1016/j.crm.2021.100307.

Jenkins, D.P., Peacock, A.D., Banfill, P.F.G., 2009. Will future low-carbon schools in the UK have an overheating problem? Build. Environ. 44 (3), 490–501. https://doi.org/10.1016/j.buildenv.2008.04.012.

Kendon, M., 2022. Unprecedented extreme heatwave, July 2022. Met Office National Climate Information Centre. Available online: ⟨https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2022/2022_03_july_heatwave.pdf⟩ (Accessed 29 July 2022).

Kendon, M., Mccarthy, M., Jevrejeva, S., Matthews, A., Sparks, T., Garforth, J., 2021. State of the UK Climate 2020. Int. J. Climatol. 41 (S2), 1–76. https://doi.org/10.1002/joc.7285.

Leite, A., Santos, A.J., Silva, S., Nunes, B., Mexia, R., Rodrigues, A.P., 2020. Assessing the use and understanding of the Portuguese heat–health warning system (ÍCARO. J. Public Health 42 (2), 395–402. https://doi.org/10.1093/pubmed/fdaa029.

Lomas, K.J., Kane, T., 2013. Summertime temperatures and thermal comfort in UK homes. Build. Res. Inf. 41 (3), 259–280. https://doi.org/10.1080/09613218.2013.757886.

Macintyre, H.L., Heaviside, C., Cai, X., Phalkey, R., 2021. The winter urban heat island: Impacts on cold-related mortality in a highly urbanized European region for present and future climate. Environ. Int. 154, 106530 https://doi.org/10.1016/j.envint.2021.106530.

Mavrogianni, A., Davies, M., Chalabi, Z., Wilkinson, P., Kolokotroni, M., Milner, J., 2009. Space heating demand and heatwave vulnerability: London domestic stock. Build. Res. Inf. 37 (5–6), 583–597. https://doi.org/10.1080/09613210903162597.

Mavrogianni, A., Pathan, A., Oikonomou, E., Biddulph, P., Symonds, P., Davies, M., 2017. Inhabitant actions and summer overheating risk in London dwellings. Build. Res. Inf. 45 (1–2), 119–142. https://doi.org/10.1080/09613218.2016.1208431.

McCartney, G., Walsh, D., Whyte, B., Collins, C., 2012. Has Scotland always been the 'sick man' of Europe? An observational study from 1855 to 2006. Eur. J. Public Health 22 (6), 756–760. https://doi.org/10.1093/eurpub/ckr136.

McCartney, G., Walsh, D., Fenton, L. & Devine, R., 2022. Resetting the course for population health: Evidence and recommendations to address stalled mortality improvements in Scotland and the rest of the UK. Glasgow Centre for Population

Health/University of Glasgow. Glasgow. Available online: ⟨https://www.gcph.co.uk/life-expectancy⟩ (Accessed 22 August 2022).
McLachlan, C., Glynn, S., Hill, F., Edwards, R., Kuriakose, J. & Wood, R., 2016. Air conditioning demand assessment. Tyndall Manchester. Available online: ⟨https://www.enwl.co.uk/globalassets/innovation/enwl001-demand-scenarios–atlas/enwl001-closedown-report/appendix-3—tyndall-uom—air-conditioning-demand-report-may2016.pdf⟩ (Accessed 20 July 2022).
Met Office (n.d.-b) What are the National Severe Weather Warning Service Impact tables?, n.d.-b. Available online: ⟨https://www.metoffice.gov.uk/weather/guides/severe-weather-advice#Rain⟩ (Accessed 04 August 2022).
Met Office (n.d.-a) UK climate averages, n.d.-a. Available online: ⟨https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvwqum6h⟩ (Accessed 07 December 2021).
Met Office (2021) Why the Met Office is launching a new extreme heat warning, Available online: ⟨https://blog.metoffice.gov.uk/2021/06/18/why-the-met-office-is-launching-a-new-extreme-heat-warning/⟩ (Accessed 04 August 2022).
Met Office, Hollis, D., McCarthy, M., Kendon, M. & Legg, T., 2022. HadUK-Grid Gridded Climate Observations on a 1km grid over the UK, v1.1.0.0 (1836–2021). NERC EDS Centre for Environmental Data Analysis.
Morgan, C., Foster, J.A., Poston, A., Sharpe, T.R., 2017. Overheating in Scotland: contributing factors in occupied homes. Build. Res. Inf. 45 (1–2), 143–156. https://doi.org/10.1080/09613218.2017.1241472.
Morgan, C., Foster, J.A., Sharpe, T. & Poston, A., 2015. Overheating in Scotland: lessons from 26 monitored low energy homes, CISBAT 2015 International Conference 'Future Buildings and Districts - Sustainability from Nano to Urban Scale'. EPFL, Lausanne, Switzerland: CHE, pp. 167–172.
Murage, P., Kovats, S., Sarran, C., Taylor, J., McInnes, R., Hajat, S., 2020. What individual and neighbourhood-level factors increase the risk of heat-related mortality? A case-crossover study of over 185,000 deaths in London using high-resolution climate datasets. Environ. Int. 134, 7. https://doi.org/10.1016/j.envint.2019.105292.
Murphy, J.M., Harris, G.R., Sexton, D.M.H., Kendon, E.J., Bett, P.E., Clark, R.T., Eagle, K.E., Fosser, G., Fung, F., Lowe, J.A., McDonald, R.E., McInnes, R.N., McSweeney, C.F., Mitchell, J.F.B., Rostron, J.W., Thornton, H.E., Tucker, S. & Yamazaki, K., 2019. UKCP18 Land Projections: Science Report. Department for Environment, Food, and Rural Affairs; Department for Business, Energy, and Industrial Strategy; MetOffice HadleyCentre; Environmen Agency. Available online: ⟨https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Land-report.pdf⟩ (Accessed 24 Apr 2020).
NRS, 2021. Life Expectancy in Scotland 2018–2020. National records of Scotland. Available online: ⟨https://www.nrscotland.gov.uk/files//statistics/life-expectancy-in-scotland/18–20/life-expectancy-18–20-report.pdf⟩ (Accessed 25 September 2021).
NRS, 2022. Projected Population of Scotland (2020-based). Released 12 Jan 2022. Created online: ⟨https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-projections/population-projections-scotland/2020-based⟩ (Accessed 11 October 2022).
Oliver, I. & Ford, L.B., 2022. Achieving a step change in the health protection response to climate change. UK Health Security Agency. Available online: ⟨https://ukhsa.blog.gov.uk/2022/10/18/achieving-a-step-change-in-the-health-protection-response-to-climate-change/⟩ (Accessed 16 November 2022).
ONS, 2022a. Excess mortality during heat-periods: 1 June to 31 August 2022. Office for National Statistics. Available online: ⟨https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/excessmortalityduringheatperiods/englandandwales1juneto31august2022#toc⟩)Accessed 10 July 2022).
ONS, 2022b. Principal projection - UK summary: 2020-based interim edition. Office for National Statistics. Released 12 Jan 2022. Created online: ⟨https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/tablea11principalprojectionuksummary⟩ (Accessed 10 October 2022).
Oudin Åström, D., Åström, C., Rekker, K., Indermitte, E., Orru, H., 2016. High summer temperatures and mortality in estonia. PLoS One 11 (5), e0155045. https://doi.org/10.1371/journal.pone.0155045.
Peacock, A.D., Jenkins, D.P., Kane, D., 2010. Investigating the potential of overheating in UK dwellings as a consequence of extant climate change. Energy Policy 38 (7), 3277–3288. https://doi.org/10.1016/j.enpol.2010.01.021.
Porritt, S.M., Cropper, P.C., Shao, L., Goodier, C.I., 2012. Ranking of interventions to reduce dwelling overheating during heat waves. Energy Build. 55, 16–27. https://doi.org/10.1016/j.enbuild.2012.01.043.
Public Health England, 2022a. Beat the heat: keep cool at home checklist. Available online: ⟨https://www.gov.uk/government/publications/heatwave-plan-for-england/beat-the-heat-keep-cool-at-home-checklist⟩ (Accessed 19 July 2022).
Public Health England, 2022b. Heatwave plan for England. Available online: ⟨https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1074023/Heatwave_Plan_for_Engand_2022_May-2022-v2.pdf#:~:text=The%20Heatwave%20Plan%20for%20England%20is%20a%20guide,health%20from%20prolonged%20exposure%20to%20severe%20heat%20for%3A⟩ (Accessed 19 May 2022).
Rahman, M.A., Franceschi, E., Pattnaik, N., Moser-Reischl, A., Hartmann, C., Paeth, H., Pretzsch, H., Rötzer, T., Pauleit, S., 2022. Spatial and temporal changes of outdoor thermal stress: influence of urban land cover types. Sci. Rep. 12 (1) https://doi.org/10.1038/s41598-021-04669-8.
Ratwatte, P., Wehling, H., Kovats, S., Landeg, O., Weston, D., 2022. Factors associated with older adults' perception of health risks of hot and cold weather event exposure: a scoping review. Front. Public Health 10, 939859. https://doi.org/10.3389/fpubh.2022.939859.
Ready Scotland (n.d.) Hot weather, n.d. Available online: ⟨https://ready.scot/respond/severe-weather/hot-weather⟩ (Accessed 19 November 2021).
Ready Scotland, 2016. Preparing Scotland: Scottish Guidance on Resilience. Philosophy, Principles, Structures, and Regulatory Duties. Available online: ⟨https://ready.scot/how-scotland-prepares/preparing-scotland-guidance/philosophy-principles-structure-and-regulatory⟩ (Accessed 04 August 2022).
Revich, B., Shaposhnikov, D., 2008. Temperature-induced excess mortality in Moscow, Russia. Int. J. Biometeorol. 52 (5), 367–374. https://doi.org/10.1007/s00484-007-0131-6.
Roberts, H., 2022. The psychology of weather forecasts. Royal Meteorological Soceity. Available online: ⟨https://www.rmets.org/metmatters/psychology-weather-forecasts#msdynttrid=-cV6VvDGnaGYZ2j32CB0nxTxsfjkIVB197appXxfn3w⟩ (Accessed 14 September 2022).
Robine, J., Cheung, S., Le Roy, S., Van Oyen, H. & Herrmann, F. , 2007. Report on excess mortality in Europe during summer 2003. European Commission. Brussels. Available online: ⟨https://ec.europa.eu/health/ph_projects/2005/action1/docs/action1_2005_a2_15_en.pdf⟩ (Accessed 23 Nov 2021).
Rocklov, J., Ebi, K., Forsberg, B., 2011. Mortality related to temperature and persistent extreme temperatures: a study of cause-specific and age-stratified mortality. Occup. Environ. Med. 68 (7), 531–536. https://doi.org/10.1136/oem.2010.058818.
Roig, E.F., 2022. Latest on Bristol's communal 'warm places' for people who can't afford heating bills, Bristol Live.2022 [Online]. Available online: ⟨https://www.bristolpost.co.uk/news/bristol-news/latest-bristols-communal-warm-places-7328983⟩ (Accessed 05 August 2022).
Sampson, N.R., Gronlund, C.J., Buxton, M.A., Catalano, L., White-Newsome, J.L., Conlon, K.C., O'Neill, M.S., Mccormick, S., Parker, E.A., 2013. Staying cool in a changing climate: Reaching vulnerable populations during heat events. Glob. Environ. Change 23 (2), 475–484. https://doi.org/10.1016/j.gloenvcha.2012.12.011.
Santamouris, M., 2015. Regulating the damaged thermostat of the cities—Status, impacts and mitigation challenges. Energy Build. 91, 43–56. https://doi.org/10.1016/j.enbuild.2015.01.027.
Schofield, L., Walsh, D., Munoz-Arroyo, R., Mccartney, G., Buchanan, D., Lawder, R., Armstrong, M., Dundas, R., Leyland, A.H., 2016. Dying younger in Scotland: trends in mortality and deprivation relative to England and Wales, 1981–2011. Health Place 40, 106–115. https://doi.org/10.1016/j.healthplace.2016.05.007.
Scottish Government, 2018. Energy Efficient Scotland. APS Group Scotland. Available online: ⟨https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2018/05/energy-efficient-scotland-route-map/documents/00534980-pdf/00534980-pdf/govscot %3Adocument/00534980.pdf⟩ (Accessed 02 November 2021).
Scottish Government, 2022. Amber warning for extreme heat extended. Available online: ⟨https://www.gov.scot/news/amber-warning-for-extreme-heat-extended/⟩ (Accessed 04 August 2022).
Scottish Government , 2023. Building standards technical handbook June 2023: domestic buildings. Available online: ⟨https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2023/02/building-standards-technical-handbook-2023-domestic/documents/building-standards-technical-handbook-2023-domestic/building-standards-technical-handbook-2023-domestic/govscot%3Adocument/2023%2BDomestic%2BTechnical %2BHandbook.pdf⟩ (Accessed 09 Mar 2023).
Scottish Parliament (n.b.) Devolved and Reserved Matters, n.b. Available online: ⟨https://www.parliament.scot/visitandlearn/Education/18642.aspx⟩ (Accessed 17 June 2020).
Sinclair, C. , 2018. Assessment of Overheating Risk in Buildings Housing Vulnerable People in Scotland. ClimateXChange. Available online: ⟨https://www.climatexchange.org.uk/research/projects/the-risk-of-overheating-in-healthcare-buildings/⟩ (Accessed).
Sniffer, 2021. Third UK Climate Change Risk Assessment Technical Report: Summary for Scotland. Available online: ⟨https://www.ukclimaterisk.org/independent-assessment-ccra3/national-summaries/⟩ (Accessed 24 June 2021).
Thomson, H., Simcock, N., Bouzarovski, S., Petrova, S., 2019. Energy poverty and indoor cooling: An overlooked issue in Europe. Energy Build. 196, 21–29. https://doi.org/10.1016/j.enbuild.2019.05.014.
Tink, V., Porritt, S., Allinson, D., Loveday, D., 2018. Measuring and mitigating overheating risk in solid wall dwellings retrofitted with internal wall insulation. Build. Environ. 141, 247–261. https://doi.org/10.1016/j.buildenv.2018.05.062.
UK Government , 2017. UK Climate Change Risk Assessment 2017. Available online: ⟨https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-2017⟩ (Accessed 08 March 2022).
Undorf, S., Allen, A., Hagg, J., Li, S., Lott, F., Metzger, M.J., Sparrow, S., Tett, S., 2020. Learning from the 2018 heatwave in the context of climate change: Are high-temperature extremes important for adaptation in Scotland. Environ. Res. Lett. https://doi.org/10.1088/1748-9326/ab6999.
Vaz Monteiro, M., Doick, K.J., Handley, P., Peace, A., 2016. The impact of greenspace size on the extent of local nocturnal air temperature cooling in London. Urban For. Urban Green. 16, 160–169. https://doi.org/10.1016/j.ufug.2016.02.008.
Walsh, D., Bendel, N., Jones, R., Hanlon, P., 2010. It's not 'just deprivation': why do equally deprived UK cities experience different health outcomes? Public Health 124 (9), 487–495. https://doi.org/10.1016/j.puhe.2010.02.006.
Walsh, D., McCartney, G., Collins, C., Taulbut, M., Batty, G.D., 2017. History, politics and vulnerability: explaining excess mortality in Scotland and Glasgow. Public Health 151, 1–12. https://doi.org/10.1016/j.puhe.2017.05.016.
Walsh, D., Mccartney, G., Minton, J., Parkinson, J., Shipton, D., Whyte, B., 2020. Changing mortality trends in countries and cities of the UK: a population-based trend

analysis. BMJ Open 10 (11), e038135. https://doi.org/10.1136/bmjopen-2020-038135.

Wan, K., Feng, Z., Hajat, S., Doherty, R.M., 2022. Temperature-related mortality and associated vulnerabilities: evidence from Scotland using extended time-series datasets. Environ. Health 21 (1). https://doi.org/10.1186/s12940-022-00912-5.

Wang, R. , 2012. Yinyang: the way of heaven and earth in Chinese thought and culture / Robin R. Wang, Loyola Marymount University. Cambridge: Cambridge University Press.

WHO Europe, 2008. Heat–health action plans. World Health Organization Europe. Available online: 〈https://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/publications/pre-2009/heathealth-action-plans〉 (Accessed 22 Nov 2021).

WHO Europe , 2021. Heat and health in the WHO European Region: updated evidence for effective prevention. Copenhagen: WHO Regional Office for Europe.

Williams, L., Erens, B., Ettelt, S., Hajat, S., Manacorda, T. & Mays, N., 2019. Evaluation of the Heatwave Plan for England: Final report. Policy Innovation and Evaluation Research Unit, Department of Health Services Research & Policy, London School of Hygiene and Tropical Medicine. 15–17 Tavistock Place, London WC1H 9SH. Available online: 〈https://piru.ac.uk/assets/files/Evaluation %20of %20the %20Heatwave %20Plan %20for %20England %20- %20Final %20Report.pdf〉 (Accessed 22 December 2020).

Wolf, J., Adger, W.N., Lorenzoni, I., 2010a. Heat waves and cold spells: an analysis of policy response and perceptions of vulnerable populations in the UK. Environ. Plan. A: Econ. Space 42 (11), 2721–2734. https://doi.org/10.1068/a42503.

Wolf, J., Adger, W.N., Lorenzoni, I., Abrahamson, V., Raine, R., 2010b. Social capital, individual responses to heat waves and climate change adaptation: an empirical study of two UK cities. Glob. Environ. Change 20 (1), 44–52. https://doi.org/10.1016/j.gloenvcha.2009.09.004.