

Commentary

Sustainable transformations for healthcare systems in a changing climate

Elena Raffetti,^{1,2,3,4,5,*} Malin Ahrne,^{6,15} Stefan Döring,^{7,8,15} Ana Hagström,^{9,10,15} Maurizio Mazzoleni,^{11,15} Gabriele Messori,^{4,5,12,15} Maria Rusca,^{13,15} and Laura Zarantonello^{14,15}

¹British Heart Foundation Cardiovascular Epidemiology Unit, Department of Public Health and Primary Care, University of Cambridge, Cambridge, UK

²Victor Phillip Dahdaleh Heart and Lung Research Institute, University of Cambridge, Cambridge, UK

³Department of Global Public Health, Karolinska Institutet, Stockholm, Sweden

⁴Swedish Centre for Impacts of Climate Extremes (climes), Uppsala University, Uppsala, Sweden

⁵Department of Earth Sciences, Uppsala University, Uppsala, Sweden

⁶Department of Women's and Children's Health, Karolinska Institutet, Stockholm, Sweden

⁷Department of Peace and Conflict Research, Uppsala University, Uppsala, Sweden

⁸Peace Research Institute Oslo, Oslo, Norway

⁹Department of Learning, Informatics, Management and Ethics, Karolinska Institutet, Stockholm, Sweden

¹⁰Centre for Epidemiology and Community Medicine, Region Stockholm, Stockholm, Sweden

¹¹Institute for Environmental Studies, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

¹²Department of Meteorology and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden

¹³Global Development Institute, The University of Manchester, Manchester, UK

¹⁴Department of Surgery, Uppsala University Hospital, Uppsala, Sweden

¹⁵These authors contributed equally

*Correspondence: er578@cam.ac.uk

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Climate extremes are unprecedented straining healthcare systems and intensifying pre-existing issues. This commentary addresses lack of (1) knowledge on unintended health consequences of adaptation actions, (2) interdisciplinary research frameworks, and (3) forward-looking, context-based scenarios. Collaboration across natural, medical, and social sciences can facilitate shifts toward more sustainable and equitable healthcare.

Introduction

Extreme climate events such as heatwaves and hurricanes place unprecedented strains on healthcare systems and access to care globally.¹ They heighten the demand for healthcare services, disrupt ongoing care, and force reallocation of resources away from healthcare to support post-event recovery. For instance, in 2012, 10 climate-related events (e.g., Hurricane Sandy and the July heatwave in Wisconsin) in the US caused \$10 billion in healthcare costs due to increased healthcare utilization.² Another prominent example is the floods in Pakistan in 2022. Around 1,000 health facilities were damaged, leaving 650,000 pregnant women in the affected areas without access to antenatal and delivery services, and 4% of the country's gross domestic product (GDP) was reallocated to the post-recovery efforts.³ Moreover, extreme climate events have complex and multifaceted impacts on health-related sectors. First, their impacts are not only direct, such as increased health-

care utilization or disruptions, but also indirect, affecting wider determinants of health such as food and water security. Second, climate-related displacement can lead to increased health vulnerabilities among displaced populations, who frequently face limited access to healthcare services. Third, impacts of climate extremes are unevenly distributed across regions and social groups, leading to cascading health inequalities. Particularly, lower-income populations and marginalized social groups are often more exposed and vulnerable to the adverse effects of climate extremes and less able to cope with the additional burden of climate-induced adverse health outcomes.⁴

Impacts of climate extremes compound existing challenges in healthcare systems.⁵ In 2021, universal health coverage significantly declined from pre-pandemic levels, with approximately 4.5 billion individuals lacking access to essential healthcare services globally.⁶ In high-income countries, an aging popu-

lation and rising non-communicable diseases are also challenging healthcare sustainability. For example, EU healthcare spending increased from 5.9% GDP in 1995 to 8.1% in 2021,⁷ with costs expected to increase further unless extensive cost-effective measures are implemented.⁸ The development of innovative treatments often leads to stringent protocols, potentially limiting access and favoring those who can afford out-of-pocket expenses over those reliant on welfare systems. The COVID-19 pandemic highlighted how pre-existing inequalities shape uneven access to health and associated outcomes for different social groups in periods of emergency (see for instance Laster Pirtle and Wright⁹). Healthcare systems are failing to meet the increasing demands generated by these interconnected stressors.⁵

These concomitant challenges highlight the urgency of a holistic approach to reforming healthcare systems, with a specific focus on understanding and addressing the impacts of climate extremes.



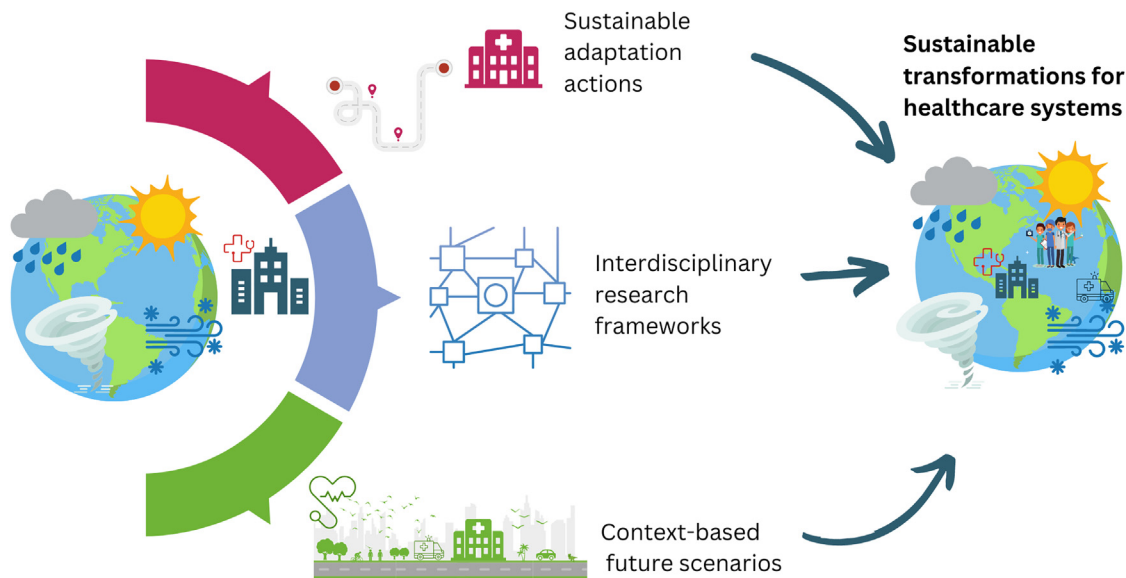


Figure 1. Sustainable transformations for healthcare systems in a changing climate

Scholars across medical, social and natural science can contribute to address this challenge developing (1) sustainable adaptation actions, (2) interdisciplinary research frameworks, and (3) context-based future scenarios.

As climate extremes become more frequent and intense, a policy paradigm rooted in social justice and inclusive adaptation is indispensable to ensure sustainability of and equitable access to healthcare. This is essential to foster sustainable policy transformations and requires systems-level changes in the institutional, political, economic, and cultural domains. In this commentary, we recognize three main challenges toward this shift that can be addressed by scholars across the natural, medical, and social sciences (summarized in Figure 1).

Lack of knowledge on unintended health consequences of adaptation actions

Healthcare systems need to be robust and resilient to multiple stressors, including climate extremes. However, climate adaptation actions often build on inadequate knowledge of the complex interplay among multiple natural and human systems. Societal responses to major climate events may thus lead to unintended consequences, such as the reduced access to certain types of healthcare, and thereby magnify social vulnerabilities. A prominent example of unintended consequence results from the extensive use of air conditioning (A/C) during a heatwave, which can exacerbate

the urban heat island effect. This, in turn, increases the exposure to extreme temperatures of those who cannot afford A/C, potentially straining healthcare services in some areas. Additionally, the high demand for electricity can lead to power blackouts, forcing emergency systems and healthcare infrastructure to rely on generators.⁹

Unintended consequences extend beyond immediate climatic events. For example, there is limited literature on cascading effects of climate extremes on specialized care highlights potentially major impacts (e.g., Phillipsborn et al.¹⁰) and large post-extreme event mortality associated with deteriorating control of chronic noncommunicable diseases, notably for hurricanes.¹¹ Six months after Hurricane Katrina (Louisiana, USA), elective care facilities were still not in place and the cost for acute care was only partially covered by Centers for Medicare and Medicaid Services.¹² Other studies underscore the potentially large vulnerability of elective surgery to the occurrence of extreme events or natural hazards: hospitals in affected areas may face infrastructure disruption and personnel shortage and need to prioritize acute surgical and anaesthesiological needs in response to the event itself.^{13,14} Next to this, recovery costs from extreme events can strain bud-

gets, reducing funds for prevention¹ and further exacerbating the negative health impacts of future extreme events.

Addressing the challenges

Sustainable adaptation pathways depend upon the development of long-term strategies that enhance inclusive adaptation and minimize unintended detrimental impacts on health and healthcare systems. Complex systems models can contribute to unraveling the complex dynamics between physical and social systems, and thus enhance our understanding of how long-term adaptation actions for climate extremes impact multiple societal dimensions.¹⁵ System dynamics and agent-based models can be used to mathematically represent the causal interplays between society, climate extremes, and adaptation actions for healthcare systems. This will contribute to the comprehension of how factors such as the severity of climate extremes, socio-economic inequalities, uncertainty in climate projections, and the diverse interests of various stakeholders could negatively affect healthcare if unsustainable adaptation actions are implemented.

Lack of targeted interdisciplinary research frameworks

Adapting healthcare systems to future climate extremes requires a socio-climatic

understanding of future impacts of climate extremes. Currently, however, analyses are entrenched in disciplinary boundaries. A case in point is Fouillet et al.,¹⁶ which used data from the 2003 heatwave in France to estimate the impact of the 2006 heatwave in the same country, predicting 6,458 deaths. This number was remarkably larger than the observed 2,062 deaths, as models did not account for the implementation of a national early warning system following the 2003 event. This discrepancy shows how societies can adapt through increased awareness and policy changes and highlights the limitations of siloed disciplinary analyses in understanding the health impacts of climate extremes in a changing climate. Public health researchers and epidemiologists need to work closer together with natural and social science scholars to tackle the complex nexus among impacts of climate extremes, sustainable health care systems, and societal processes.

Addressing the challenges

Recognizing that our systems are complex and change over time is essential to understand the ongoing macro-level adaptations and behavioral modifications that occur in response to climate extremes. Only an interdisciplinary approach that transcends traditional siloed methods can enable the development of comprehensive public health interventions, community support systems, and policy measures that meet the diverse and complex needs emerging from climate extremes. We call for research that not only spans across various disciplines but also actively integrates insights from medical sciences, climate science, and social sciences to examine how context-specific factors including cultural norms economic and policy visions and social textures shape access to healthcare systems in different geographical contexts. This collaborative effort is necessary to develop a comprehensive understanding of the multifaceted impacts of climate change on and unequal access to healthcare systems.

Lack of context-based future scenarios

Building healthcare systems that are resilient to the societal and health consequences of future, possibly unprecedented, climate extremes requires

context-specific, actionable climate information. Historically, public health and epidemiology research has leaned heavily on retrospective analyses. This approach can fall short in preparing for unprecedented extreme events. The COVID-19 pandemic has been a prominent example of the critical importance of modeling future health scenarios. Additionally, much of the available information from climate change research takes the form of climate scenarios focusing on large-scale analyses (national to global) and encompassing model and socioeconomic pathway uncertainty. The available information is thus extensive, but hard to utilize by non-specialists as knowledge basis for concrete actions at local to regional scales.

Addressing the challenges

A potential approach to bridge this gap and provide actionable knowledge is to develop context-specific storylines: a non-probabilistic approach that delineates plausible future scenarios, without assigning a probability to them.¹⁷

The information from climate scenarios is used qualitatively to identify possible future extremes and relate them to local impacts. Yet, the traditional storyline approach overlooks socio-political drivers of adaptation, including the role of power, differential agency, and economic inequalities in shaping the genesis and outcomes of climate extremes.¹⁸ We thus propose a new type of storyline that incorporates an understanding of the institutional, political, economic, and cultural context of the healthcare system at the location of interest. In order to make the narrative robust, one can rely on an analysis of past climate extremes and responses at the location of interest for specific climate extremes (e.g., floods, hurricane, drought) and additionally draw insights from the impacts of and responses to climate extremes at other comparable locations. A concrete example could be building a storyline for the healthcare consequences of a future, unprecedented heatwave in southern Sweden. Sweden, like much of the northern midlatitudes, is expected to experience a faster-than-global-average temperature rise and a significant increase in the duration and extent of future heatwaves.¹⁹ Therefore, it is reasonable to expect that, in the coming decades, southern Sweden may experience heatwaves far exceeding the current temperature record of just above 36°C.

Past heatwaves in Sweden have not been sufficiently intense enough to strain the healthcare system, yet examples from continental Europe—notably the summers of 2003 and 2022—show the pressure that unprecedented temperatures can place on healthcare. Moreover, the COVID-19 pandemic has highlighted that the Swedish healthcare system struggles to rapidly expand hospital capacity in the face of sudden and unexpected public health threats. This limitation amplifies inequalities in access to health and leads to extensive cancellation of specialized healthcare due to lack of staff, material, and medications.²⁰ Based on this, a detailed storyline could be built around a future heatwave reaching around 40°C, leading to large excess mortality among the elderly and those with chronic health conditions, while placing extreme strain on emergency health services and hospitals. A key advantage of the storyline approach is that it can be flexibly adapted to different categories of climate extremes, including those that are difficult to capture in numerical models, such as rain-driven flooding. Moreover, storylines can be adapted to account for the compounding of different climatic hazards or the compounding of climate-related impacts with other societal or environmental stressors. The storyline approach thus has the potential to provide impact-focused understandings of future climate impacts on healthcare systems at a given location.

Conclusions

The sustainable adaptation of healthcare systems to climate change is a complex, urgent task requiring a multifaceted approach. This commentary calls on scholars to enhance knowledge, foster interdisciplinary collaborations, and develop context-specific future scenarios. Such an effort will not only contribute to addressing the immediate challenges posed by climate extremes to healthcare systems but will also ensure long-term resilience and equitable access to healthcare for all, especially the most vulnerable sectors of the population.

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DECLARATION OF INTERESTS

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