research

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Rainfall events and adverse health outcomes

ORIGINAL RESEARCH Two stage time series analysis

Rainfall events and daily mortality across 645 global locations

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Study question What are the associations between characteristics of daily rainfall (intensity, duration, and frequency) and all cause, cardiovascular, and respiratory mortality across diverse global locations?

Methods This study used a two stage time series analysis of daily mortality data from 645 locations across 34 countries or regions, and comprised a total of 109 954 744 all cause deaths, 31 164 161 cardiovascular deaths, and 11 817 278 respiratory deaths from 1980 to 2020. The main outcome measure was the association between daily mortality and rainfall events with return periods of one year, two years, and five years. The return period is the expected average time between occurrences of an extreme event of a certain magnitude. A continuous relative intensity index was used to generate intensity-response curves to estimate mortality risks at a global scale. A 14 day lag period was applied to account for delayed effects. To illustrate the gradation of relative risk associated with increasing rainfall intensity from relatively moderate to extreme, a continuous variable, denoted as PE_2, was used for the percentage of daily accumulated rainfall exceeding the two year return period threshold. This measure provides a continuous index for quantifying the relative intensity of extreme rainfall events. To investigate how various factors might modify the health effects of extreme rainfall events across different populations, we applied random effects meta-regressions with maximum likelihood estimation. The potential effect modifiers examined included: the classification of local climate types, the amount of total annual precipitation, the yearly average standard deviation of precipitation on rainfall days, economic status, population density, and the average vegetation coverage rate.

Study answer and limitations During the study period, a total of 50 913 rainfall events with a one year return period, 8362 events with a two year return period, and 3301 events with a five year return period were identified. A day of extreme rainfall with a five year return period was significantly associated with increased daily all cause, cardiovascular, and respiratory mortality, with cumulative relative risks across 0-14 lag days of 1.08 (95% confidence interval 1.05 to 1.11), 1.05 (1.02 to 1.08), and 1.29 (1.19 to 1.39), respectively. Rainfall events with a two year return period were associated with respiratory mortality only, whereas no significant associations were found for events with a one year return period. Non-linear analysis revealed protective

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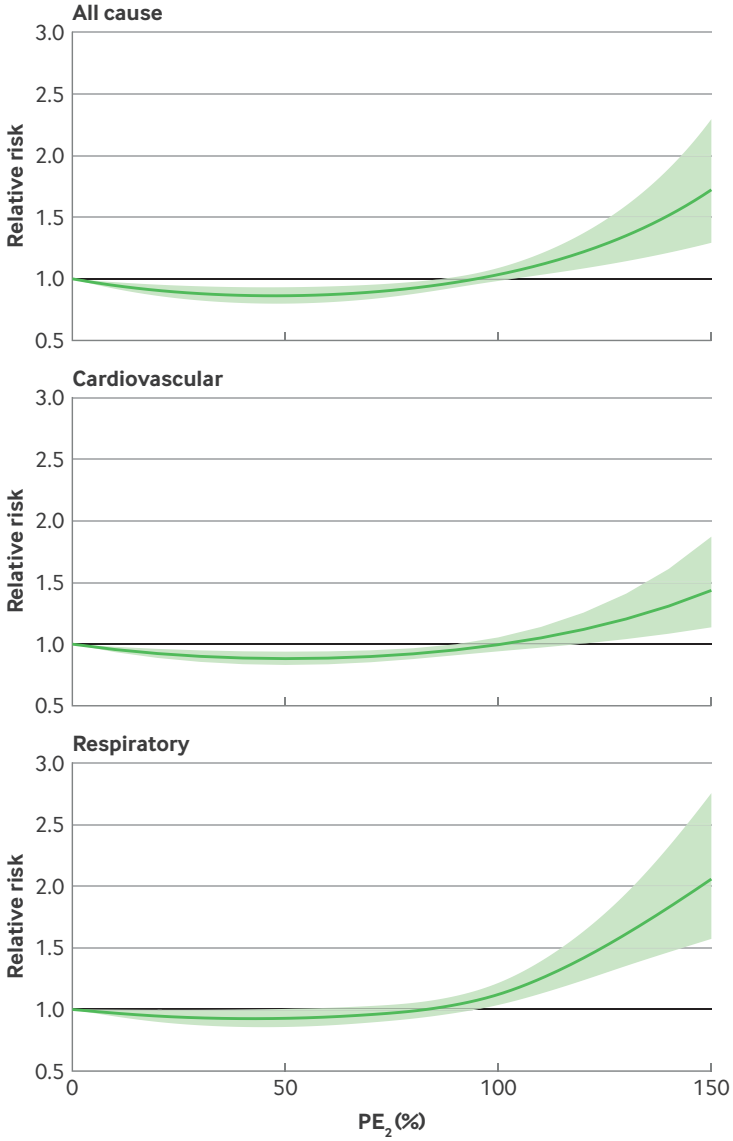
effects (relative risk <1) with moderate-heavy rainfall events, shifting to adverse effects (relative risk >1) with extreme intensities. These findings suggest that moderate rainfall may confer health benefits, possibly by improving air quality or alleviating heat stress, whereas extreme rainfall poses substantial health risks. The increased mortality associated with extreme rainfall highlights the vulnerability of populations during such events. Additionally, mortality risks from extreme rainfall events appeared to be modified by climate type, baseline variability in rainfall, and vegetation coverage. Locations with lower variability of baseline rainfall or scarce vegetation coverage showed higher risks. However, there was no significant evidence that average annual precipitation and population density modified these associations. Limitations included the inability to capture granular details of individual factors such as age, sex, race, urban/rural residence, or specific clinical settings. Also, although the analysis included 34 major countries or regions on six continents, the analysed locations were mainly located in east Asia, Europe, and North America, with fewer in Latin America and Africa, limiting the global representativeness of the estimated risks.

What this study adds This study found that daily rainfall intensity was associated with varying health effects, with extreme events linked to an increasing relative risk for all cause, cardiovascular, and respiratory mortality. The observed associations varied with local climate and urban infrastructure. Locations with lower variability of baseline rainfall or scarce vegetation coverage showed higher risks. The findings highlight the complex association between rainfall intensity and health outcomes, emphasising the need for adaptive public health measures. Policy makers should integrate health services with climate adaptation plans to protect vulnerable populations during extreme weather events.



Exposure-response function of the relative risks of all cause, cardiovascular, and respiratory mortality associated with daily accumulated rainfall exceeding the two year return period threshold (PE_2). The return period is the expected average time between occurrences of an extreme event of a certain magnitude

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Climate change involves progressively more extreme weather events, leading to an increase in risk of adverse health outcomes. In their paper, He and colleagues found that rainfall events with a five year return period—in meteorological terms, intense rainfall events that are expected to occur every five years—were associated with an 8% increase in all cause mortality, a 5% increase in cardiovascular mortality, and a noticeable 29% increase in respiratory mortality during a 0-14 day period after the rainfall event.[1]

Three novel features of the study are particularly noteworthy. Firstly, the authors used an intensity-duration-frequency model to analyse rainfall events, which offered more insights than traditional single metric analyses. Secondly, rainfall has dual positive and negative effects on health, and moderate to heavy rainfall showed protective effects (relative risk <1) by potentially reducing air pollution and promoting behaviours such as staying indoors. At extreme rainfall levels, however, the protective effects diminished, and the relative risk shifted to harm (relative risk >1), possibly through damage to infrastructure, water contamination from sewerage overflow, and exposure to harmful microorganisms. Thirdly, the study's extensive global scope—encompassing 645 locations across 34 countries—highlighted varying regional differences in mortality risks, uncovering factors that contributed to local resilience.[1]

Champion climate health

Although the association between meteorology and medicine might seem an emerging specialty, the two share a history. A report in 1924 and republished in 2024 described how doctors in the 19th century used rudimentary weather diaries to track health outcomes.[2] For example, sunlight was observed to have beneficial properties that helped in the treatment of tuberculosis and rickets, a connection we now understand through the role of ultraviolet light in stimulating vitamin D synthesis, calcium absorption, and boosting immune mechanisms against infections. Even without full scientific explanations, health professionals intuitively recognised the connection with climate health, written a century ago: "Climatology, from the human standpoint, has not yet reached the dignity of an exact science."[2] Today, symbiosis is growing between observational studies and physiological research in climate health. New tools, including advanced models, satellite imaging, and biological approaches such as environmental epigenetics, are enhancing our understanding—offering an opportunity to refine the previously inexact science.

AGENCJA FOTOGRAFICZNA CARO/ALAMY

Regions with higher vegetation coverage are more resilient to the health effects of extreme rainfall

Health professionals are among the most trusted members of society and are ideally placed to drive both individual and systemic climate action by educating patients about climate related health risks and fostering resilience within communities. In the Anthropocene, health professionals are called on to expand the interpretation of primum non nocere (first, do no harm) and beneficence to include the health of the planet as fundamental to human wellbeing.[3] One practical resource for health professionals to fulfil this role is a BMJ Practice Pointer article that offers guidance on climate sensitive health hazards during healthcare screenings, patient history taking, management of long term conditions, discharge planning, and the promotion of civic engagement.[4]

Vegetation coverage as adaptation

An area beyond the direct control of health professionals but critical to how health systems adapt to climate change is vegetation coverage, which serves as a strategy to reduce the effects of climate change. Previous research consistently found that green spaces were associated with better health outcomes by promoting healthy lifestyles, enhancing wellbeing, and mitigating heat related illnesses such as heat exhaustion and heat stroke.[5] He and colleagues' study builds on these findings by showing that regions with higher vegetation coverage are more resilient to the health effects of extreme rainfall. The study found that vegetation coverage was a more important factor influencing health outcomes during extreme rainfall events than annual average precipitation or population density.[1] Vegetation helps to absorb excess rainwater, stabilise soil, and reduce surface run-off, thereby lessening the harmful effects of flooding and the spread of waterborne diseases.

The urgency of the climate crisis is echoed by the editors of more than 200 medical journals, including *The BMJ*, who have declared it the greatest threat to health.[6] Yet, despite the clear science, climate action remains difficult. The novelist John Steinbeck offered an analogy in his book *East of Eden*,[7] describing California's Salinas Valley as follows:

> *I have spoken of the rich years when the rainfall was plentiful. But there were dry years too, and they put a terror on the valley. The water came in a thirty-year cycle . . . And it never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years. It was always that way*

People often forget the lessons of scarcity during times of abundance—a risky form of amnesia for climate change. The stakes are far too high, for when it rains, it pours—and in this era of escalating climate extremes, it will pour harder than ever before.

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ORIGINAL RESEARCH Systematic review

Strategies and tactics to reduce the impact of healthcare on climate change

Braithwaite J, Smith CL, Leask E, et al

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Study question How can healthcare systems mitigate their carbon footprint, which is currently estimated to be more than 4.4% of global emissions?

Methods Empirical studies and grey literature were reviewed to examine how healthcare systems are limiting their greenhouse gas emissions. Eight databases and authoritative reports were searched from inception dates to November 2023. Teams of investigators screened relevant publications against the inclusion criteria (eg, written in English, discussed impact of healthcare systems on climate change), applying four quality appraisal tools. Inductive analysis was used to identify major themes, and reporting was conducted in accordance with the PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines.

Study answer and limitations Of 33 737 publications identified, 205 were included after screening and full text review. More than half of the publications (51.5%) addressed the macro level of the healthcare system (including national or global systems). Nine themes were identified: changing clinical and surgical practices (n=107); enacting policies and governance (n=97); managing physical waste (n=83); changing organisational behaviour (n=76); actions of individuals and groups (eg, advocacy, community involvement; n=74); minimising travel and transportation (n=70); using tools for measuring greenhouse gas emissions (n=70); reducing emissions related to infrastructure (n=63); and decarbonising the supply chain (n=48). The review included papers and authoritative reports written in English, and so some relevant papers could have been omitted. Most of the included literature discussed high income country healthcare systems, which is a well known bias.

The carbon footprint of healthcare systems is estimated to be more than 4.4% of global emissions

What this study adds The results of this systematic review provide a comprehensive overview of overarching strategies and specific tactics, models, and tools that can be implemented to decarbonise healthcare systems with the aim of reaching net zero emissions by 2050.

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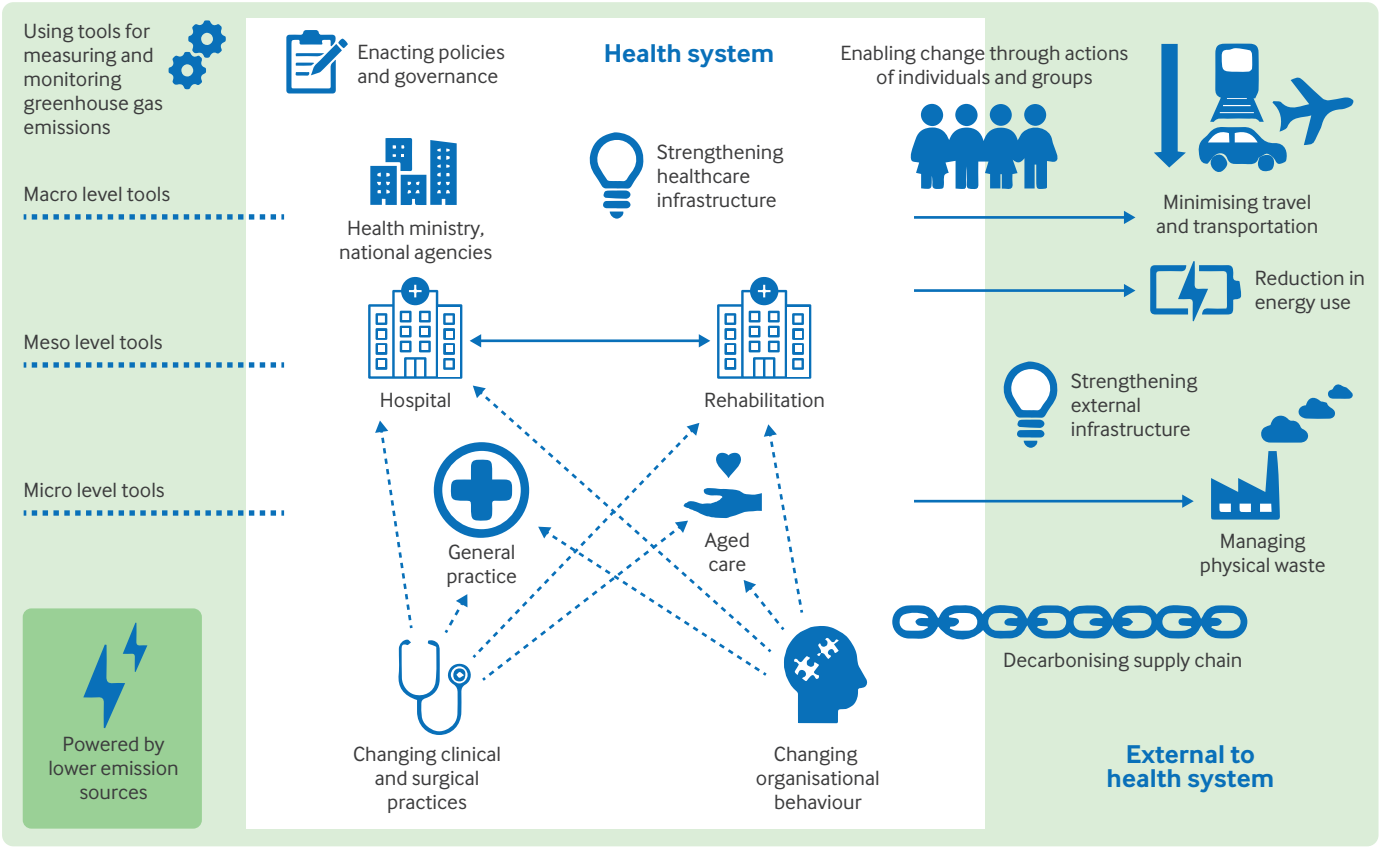
Systematic review registration PROSPERO CRD42022383719.



Strategies and tactics for reducing healthcare system greenhouse gas emissions according to healthcare system level: micro (eg, frontline clinician, including healthcare delivery at a clinic, department, whole hospital, or facility), meso (regional or network level, eg, health district, hospital network), macro (whole healthcare system, including national or global systems)