Perspective

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Under the weather: an epidemic thunderstorm asthma event in Leicester, June 2023

Sarah Diver [1,2] Fiona Symon,[1] Jack Satchwell,[1,3] Heather Lipscombe,[4] Ruth H Green,[1,2] Gerrit Woltmann [2] Damian Roland [5,6] Erol A Gaillard,[1,7] Anna Hansell,[3,8] Chris Brightling,[1,2] Leah Cuthbertson[1,3]

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ABSTRACT

In the context of climate change and increasing global populations, thunderstorm asthma may become a greater threat at both individual and population levels. The unpredictable nature of epidemic thunderstorm asthma events makes them challenging to study; however, they can have devastating consequences. Novel approaches are required to characterise the mechanisms driving these events to allow researchers and other stakeholders to understand who is at risk and when. This will support the development of interventions that protect patients and healthcare services. In this commentary, we provide an overview of thunderstorm asthma and briefly describe an epidemic affecting Leicester, UK in June 2023. Our analysis highlights *Cladosporium* spores as a key player in mediating UK thunderstorm asthma. Low levels of background treatment in adults and an increase in emergency assessments but not hospitalisations in children suggest that epidemics could be prevented by improving awareness and ensuring access to standard inhaled therapies. Finally, we consider future risk and suggest research priorities with an ultimate goal of minimising the adverse impact related to thunderstorm asthma going forward.

INTRODUCTION

The unprecedented rise in global temperatures due to accumulating greenhouse gases in the atmosphere will continue to impact human health through a range of mechanisms: direct effects from extreme weather events, consequences of rising sea levels on crop growth and vectorborne infectious diseases and social effects relating to higher demand for increasingly limited resources. A significant increase in global morbidity and mortality related to climate change is predicted by 2050,[1] with the WHO predicting 250 000 excess deaths per year related to climate change between 2030 and 2050.[2] These consequences will disproportionately affect those in low-income or disadvantaged countries and communities with resultant widening of health inequalities within and between populations.

In the context of global warming, aeroallergen seasons may begin earlier and last longer, already shown for recent decades in the UK,[3] with susceptible individuals demonstrating prolonged sensitisation between seasons. This can lead to the development of allergic diseases, such as allergic rhinitis and asthma, and/or poor control of symptoms. The global burden of allergic disease has increased exponentially,[4] and allergic conditions are predicted to affect 4 billion people by 2050.[5] Asthma is also increasing in prevalence. In the UK, asthma is diagnosed in 12% of the population, more than all other chronic respiratory disease diagnoses combined,[6] with related healthcare contacts and hospitalisations placing a considerable burden on healthcare services.

Thunderstorm asthma (TSA) is a phenomenon characterised by increased respiratory symptoms that occur in relation to a rapid and significant aeroallergen exposure triggered by thunderstorm weather. Where this worsening of symptoms necessitates additional treatment, it is termed an asthma attack or exacerbation. These are important events both at an individual level, associated with accelerated lung function decline and poor disease control, but also at the population level. High numbers of asthma exacerbations occurring simultaneously can place a huge strain on primary and secondary healthcare services, negatively impacting their capacity to function. The unpredictable nature of TSA events makes them challenging to study, and therefore evidence is lacking for how to prevent them.

In this commentary, we will discuss what is known about TSA, describe an event affecting the UK in June 2023 and highlight important areas for future research and clinical care.

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For numbered affiliations see end of article.

Correspondence to
Dr Sarah Diver;
sed22@le.ac.uk

BACKGROUND

TSA was first characterised in Birmingham, UK, in 1983,[7] with over 20 further events reported since. Events have been reported across the globe, including in the UK, Australia, Europe, North America and the Middle East. The term TSA describes the occurrence of symptoms in an individual patient. 'Epidemic thunderstorm asthma' (ETSA) reflects a population-level event. ETSA occurs when TSA affects a sufficiently large population, such as across urban centres, leading to rapid and localised outbreaks of cases with associated impacts on healthcare services.

Prospective clinical and mechanistic studies are understandably lacking due to the challenges of collecting high-quality data with minimal preparation; however, retrospective analyses monitoring aeroallergen levels alongside meteorological data have provided insight into how these events are mediated. Specific aeroallergens vary by geographical location. For example, rye grass pollen, specifically *Lolium perenne 5*,[8] is thought to be responsible for the largest ETSA event recorded to date affecting Melbourne, Australia, in 2016.[9] In contrast, elevated levels of fungal spores including *Alternaria*,[10] *Cladosporium*[11] and *Didymella*[12] have been recorded in the context of ETSA events affecting the UK, although the mechanistic role of fungal spores is subject to debate. Gust fronts, downdrafts and outflows transport and concentrate allergenic particles close to ground level. Fragmentation of larger allergenic particles like pollen grains also occurs. Grains that have undergone rupture subsequently become small enough to evade filtration by the nasopharynx and enter the lower respiratory tract where they trigger the airway inflammation responsible for the clinical manifestations of disease. While conclusive evidence is lacking, a number of mechanisms of pollen rupture have been proposed, including osmotic stress, mechanical friction or electrical activity.[13]

Studies characterising the populations affected in historical events have similarly provided information on risk factors for TSA. These have reviewed risk factors for hospitalisation and intensive care support and a review of fatalities. Events predominantly affect working age groups with a male predominance,[9] perhaps reflecting specific occupational risk factors. The vast majority of patients have a history of atopy[10 14] with other risk factors for severe TSA including a known asthma diagnosis at the time of presentation, a history of exacerbation in the previous 12 months and a lack of inhaled corticosteroid (ICS) treatment.[14] Biological characterisation has demonstrated higher levels of the type 2 biomarkers, blood eosinophils and fractional exhaled nitric oxide (FeNO) in those more severely affected.[15]

Studies of the Melbourne event have consistently highlighted an increased risk of TSA in those of Asian ethnicity, from analyses of healthcare workers[16] to those including hospitalised patients and specifically requiring higher level support.[9] One study demonstrated an increased risk of hospitalisation specifically in second-generation Asian immigrants.[14] This suggests that susceptibility may be due to a gene–environment interaction rather than an effect of migration-associated health, social or cultural characteristics. Asian ethnicity was associated with an increased risk of the most serious complications.[9] Characterising the basis of this increased risk is clearly important to prevent morbidity and mortality on an individual level. In addition, achieving better insight into adverse host–environment interactions in a condition as common as asthma could impact at a population level and facilitate a reduction in disease-related health inequality.

Multiple analyses have reported the impact of the Melbourne 2016 event on different healthcare settings to understand the resource and economic implications. The event was associated with >1000 excess emergency calls related to respiratory distress, a 6.7-fold increase in emergency department (ED) attendances for respiratory complaints and an almost 10-fold increase in hospitalisations for acute asthma,[9] while primary care saw a 7-fold increase in asthma-related consults.[17] Qualitative evaluation highlighted limited information sharing in real time and insufficient space, staff, equipment and medication to provide adequate care.[18] Importantly, longitudinal follow-up of TSA to 3 years suggests that these events are associated with the persistence of asthma symptoms or worsening of disease control following the initial event, both in groups with a prior diagnosis of asthma and in those with a new diagnosis in the context of the event.[19]

TSA IN LEICESTER, UK, JUNE 2023

Using a combination of national and local emergency and acute care data, we identified an ETSA event affecting England in June 2023 and briefly describe both the local clinical impact and environmental conditions associated with the event.

Publicly available UK Health Security Agency syndromic surveillance data confirmed a sharp increase in contacts reporting asthma and difficulty breathing across surveillance systems on 11–12 June 2023 and 18 June 2023, coinciding with Met Office warnings of thunderstorms across parts of England. There was a dramatic increase in ED attendances due to asthma across all regions of England with the exception of the North East (figure 1).[20] Consistent with previous TSA events,[21] effects were observed in those aged 5–64 years. Locally, 149 ED presentations were recorded on 12–13 June (figure 2), a 6.6-fold increase above the 3-year average. There was a related increase in hospitalisations for adults, but not paediatric, acute asthma, with 29 cases admitted on 12–13 June, a 5.9-fold increase. Following the storm on 18 June, there was a further spike in adult hospitalisations for acute asthma with 22 cases recorded (a 4.5-fold increase) on 18–19 June.

A comparison of adult patients hospitalised for asthma prior to and at the time of the 12 June 2023 thunderstorm showed that ethnic minorities were disproportionately affected. Atopy was more common in thunderstorm

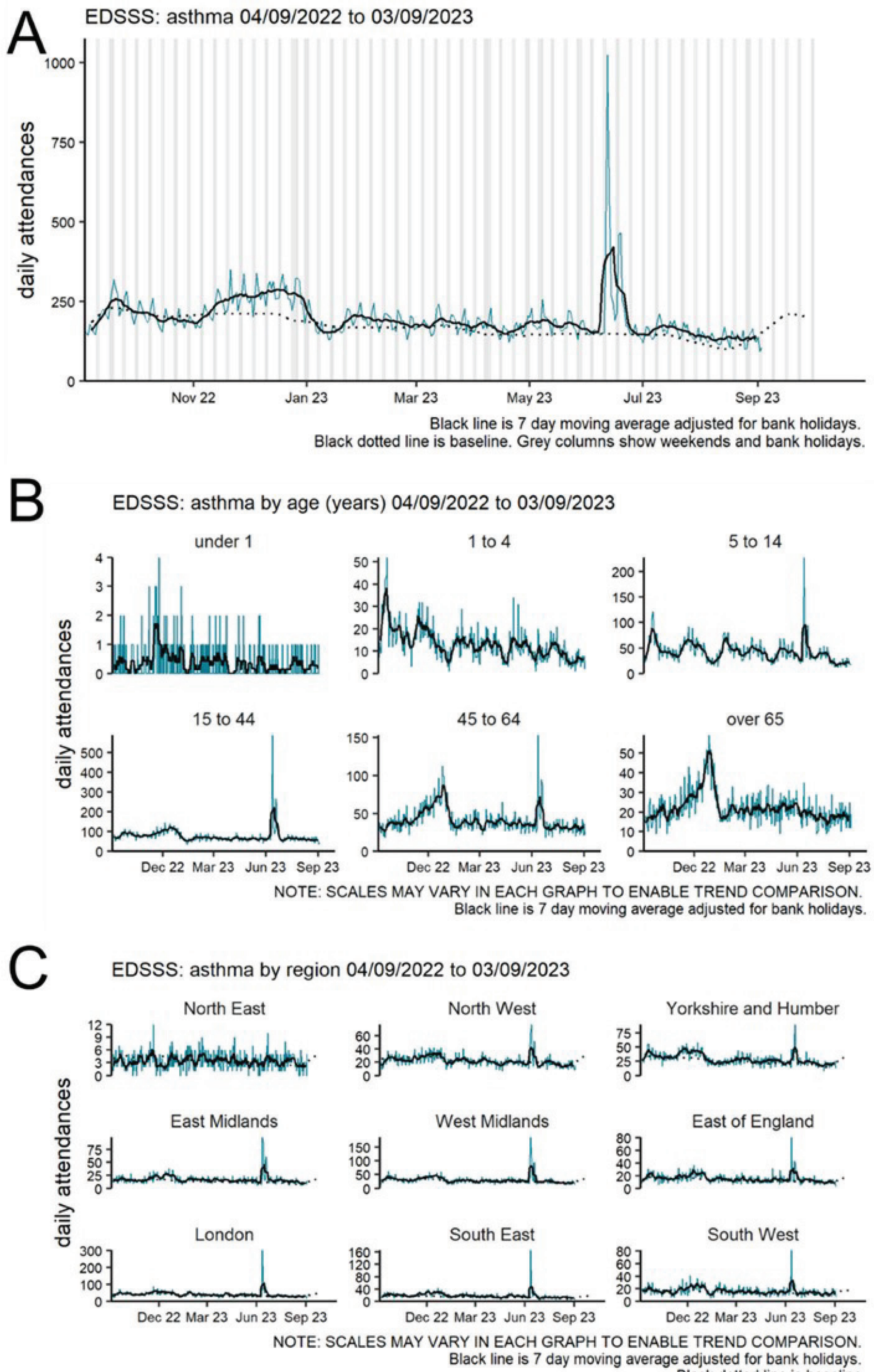

Figure 1 UK Health Security Agency (HSA) data for England demonstrating trends in emergency department attendances for acute asthma from Autumn 22 to Autumn 23, with (A) overall spikes at the time of thunderstorms on 12 and 18 June 23, (B) spikes in patients aged 5–64 and (C) spikes across all regions of England with the exception of the North East. Figures adapted from the Emergency Department Syndromic Surveillance System Bulletin (England), 2023, Week 35 with permission as per the terms of the Open Government License (OGL) V.3.0. EDSSS, emergency department syndromic surveillance system.

cases, but age was similar between the groups. In contrast to previous events, more females than males were hospitalised. Baseline ICS dose was low; patients had few comorbidities and a shorter length of hospitalisation, suggesting an uncomplicated response to standard therapies. Good treatment response in most is likely to explain the lack of hospitalisations observed in children despite the spike in emergency assessments. Almost one-quarter of adults admitted with TSA did not have an established diagnosis of asthma at the time of hospitalisation.

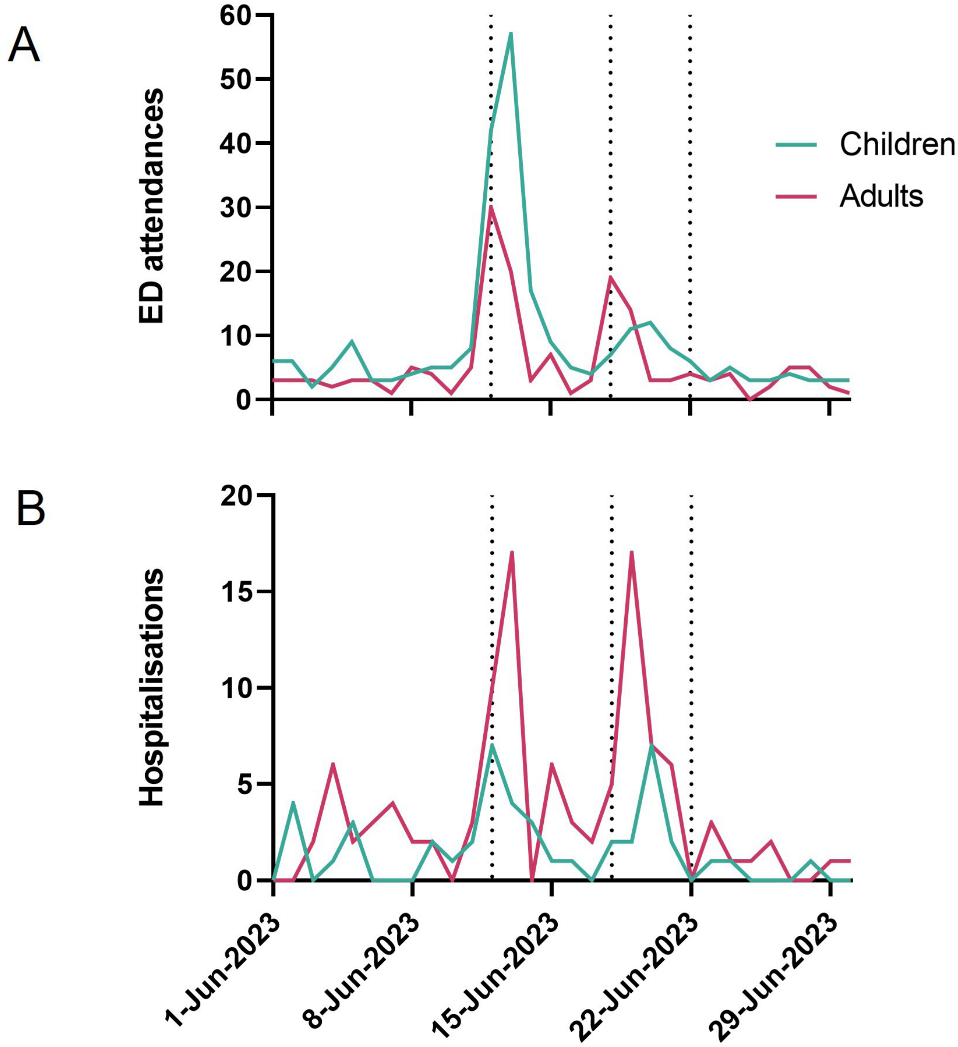

Figure 2 University Hospitals of Leicester NHS Trust (A) emergency department (ED) attendances and (B) hospitalisations for acute asthma in adults (red) and asthma or viral wheeze in children (green) across June 2023. Vertical dotted lines indicate thunderstorm days. Adult hospitalisations for acute asthma represent admissions to Glenfield Hospital site only. NHS, National Health Service.

Pollen and fungal spore levels are routinely monitored in Leicester using a 7-day volumetric spore trap (Burkard Manufacturing) and quantified according to standard procedures set out by the British Aerobiology Federation (BAF).[22] Daily grass pollen and *Cladosporium* levels May–August 2023 are shown alongside ED attendances for adult asthma in figure 3. A spike in *Cladosporium* spore levels was observed on 12 and 22 June, coinciding with thunderstorms. *Cladosporium* levels were lower on 18 June, although still in excess of the allergenic threshold,[23] with the majority of these spores observed at the time the storm commenced. Levels of ascospores were high on both 12 and 18 June (figure 4); however, heterogeneity within this grouping limits interpretation. Spikes in other types of fungal spores were not observed. Grass pollen levels dropped on the thunderstorm days compared with the preceding day, except for 22 June when a small increase was observed. Levels were in excess of the allergenic threshold[24] on all thunderstorm days.

These initial analyses support a mechanistic role for fungal spores in mediating TSA, at least locally; however, the relationship between spore count and healthcare usage does not appear to be direct. While the spike in *Cladosporium* spore count on 12 June was associated with an increase in hospitalisations, the subsequent spike during the thunderstorm on 22 June was not. Conversely, a spike in hospital admissions at the time of the thunderstorm on 18 June was associated with lower levels of *Cladosporium* at the time of the storm, although still at levels associated with clinical allergy. The impact of elevated levels of other aeroallergens such as grass pollen in the hours and days prior to the thunderstorms is unclear, likewise the contribution of changes in patient behaviour in response to the earliest event.

In Leicester City, >65% of the population belong to ethnic minority groups;[25] therefore, the disproportionate effect on ethnicities other than white is of specific interest. Understanding the basis of increased risk in these patients

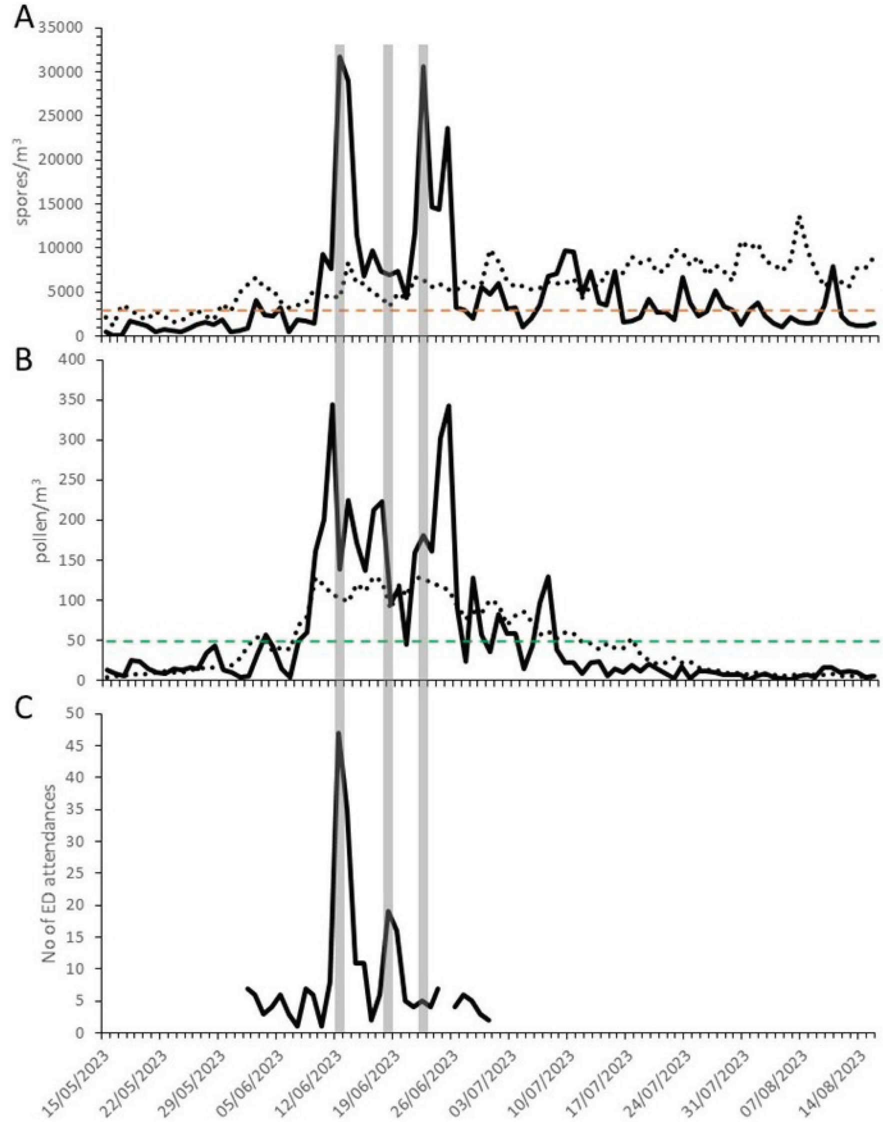

Figure 3 *Cladosporium* spore counts, (A) grass pollen counts (B) and adult asthma emergency department (ED) attendances (C) May–August 2023. Thunderstorm days on 12, 18 and 22 June 2023 are indicated by the grey columns. Black dotted lines indicate average spore (A) and pollen (B) levels based on 17 years of data collected in Leicester, UK. Orange dotted line indicates allergenic threshold of 3000 spores/m^3 for *Cladosporium* (A). Green dotted line indicates allergenic threshold of 50 pollen grains/m^3 for grass (B).

could allow better targeting of public health advice and risk reduction strategies. The low levels of background treatment observed in those affected by TSA also suggest that the burden of future events on healthcare services could be reduced through targeted public health advice and optimised self-management if evidence to support their implementation can be obtained.

FUTURE RISK

Understanding the potential future risk from ETSA is based on predicting the frequency of these events going forward, but also evaluating how well-prepared healthcare services are for a rapid and unpredictable increase in demand.

ETSA events occur as a result of the combined trifecta of meteorological conditions, high aeroallergen levels and a large susceptible population.

Climate change predictions for the UK indicate generalised increases in rainfall and temperature, in parallel with an increase in extreme weather events.[26 27] This is likely to lead to increased pollen and fungal spore levels[3] and create conditions that increase aeroallergen concentrations in the air. While no real change in thunderstorm frequency or the seasonal pattern of storms has been observed in the UK over the 30 years to 2019,[28] characteristics other than frequency and timing may also mediate risk. For example, storm intensity may also be important. Increasingly sophisticated prediction models suggest that greater convective instability will affect the UK by the end

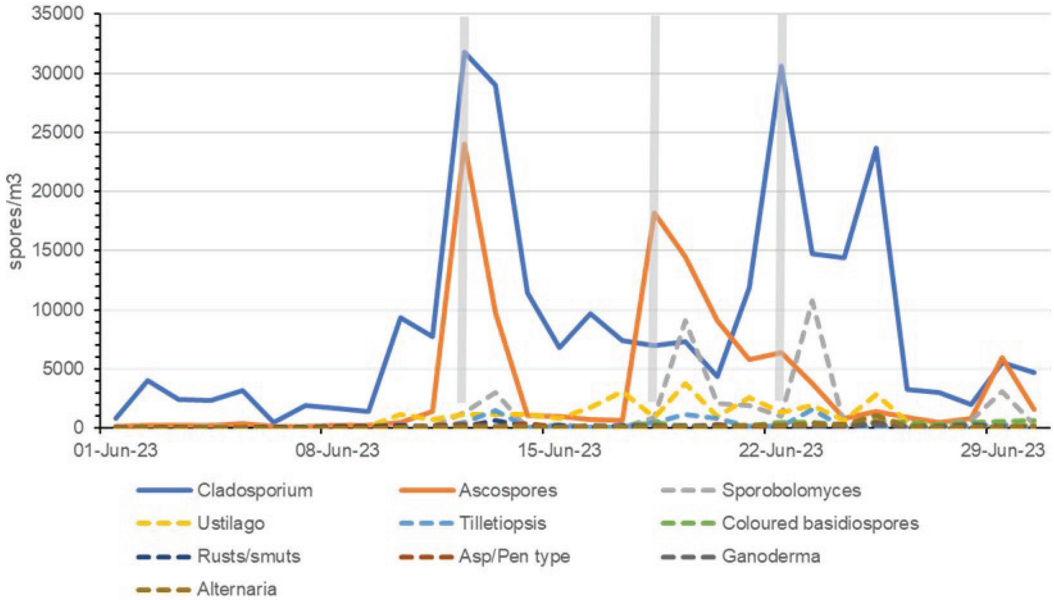

Figure 4 10 most abundant fungal spore categories recorded for June 2023. Thunderstorm days on 12, 18 and 22 June 2023 are indicated by the grey columns.

of the 21st century. This could increase the fraction of thunderstorms causing severe weather, particularly in higher emissions scenarios.[29]

Global warming will likely facilitate a general increase in some fungal spores known to be allergenic such as *Alternaria*. However, evaluation of allergenicity in the many thousands of fungal spores that humans are exposed to in outdoor air is in its infancy, and therefore understanding of allergen-associated risk is limited. Extended monitoring networks, including those with the capacity for real-time monitoring, will be integral in providing further insight in the future. High temporal and spatial variation in pollen seasons is likely to continue and makes prediction of short-term impact on health challenging. Forecasting is further complicated by other dynamic factors such as land use. While allergenic thresholds are defined in previous studies, storm damage may mean allergens have an enhanced effect in epidemic events. Fragmented or damaged particles may not be detected in routine monitoring. Sensitisation and exposure to multiple allergens in concert may also be important. These and other gaps in knowledge make the prediction of future risk challenging.

Asthma and allergic disorders are increasing over time, alongside total UK population growth. Herein lies the most significant danger associated with future ETSA events. Both prepandemic and increasingly now postpandemic, the UK National Health Service is under increasing strain due to a multitude of issues that include increasing demand from an ageing and multimorbid population and the adult social care crisis. Bed occupancy is high, and there are increasing waits for emergency treatment, indicating a drastically reduced capacity to cope with spikes in demand in the context of major incidents. Healthcare services were overwhelmed in Melbourne in 2016, and in response to this event, the Australian government has prioritised public and organisational awareness of ETSA to avoid further instances of preventable fatality.[30] We suggest that learning lessons from colleagues in Australia and prioritising research to protect the NHS against ETSA could help to prevent a similar tragedy in the UK.

RESEARCH PRIORITIES

The prioritisation of clinical research was a key success of the UK COVID-19 pandemic response and has led to widespread recognition of the importance of being prepared to collect and analyse data related to unpredictable phenomena that impact on health. The scale and complexity of ETSA events lend themselves to the application of technological advancements on both the clinical and environmental sides. Smartphone-based apps could facilitate near-patient monitoring, and wearable devices may provide digital biomarkers of risk. Increasingly sophisticated monitoring systems will provide real-time aeroallergen data, and artificial intelligence will provide more accurate and prolonged environmental forecasting. These, and other, strategies could help to gather evidence to determine who is at risk and when and what interventions might help to protect individuals and healthcare services.

We propose five research priorities related to the prevention of ETSA in the UK:

1. Characterise the environmental conditions required to drive ETSA events through a combination of retrospective analysis and model systems, specifically including the formation of longer-term, extended fungal spore monitoring networks.

2. Identify novel methods of passive data collection that allow prospective study of future events.
3. Characterise affected populations sufficiently to understand how to target risk reduction interventions, particularly to those with no previous asthma diagnosis.
4. Characterise the basis of increased risk in ethnic minority and other population subgroups and involve patient and public representatives from specific at-risk groups or communities to maximise the effectiveness of risk reduction strategies.
5. Evaluate the feasibility and effectiveness of environmental warning systems to guide self-management interventions that protect patients and healthcare services.

Author affiliations
[1]Department of Respiratory Sciences, College of Life Sciences, University of Leicester, Leicester, UK
[2]Respiratory Medicine, Glenfield Hospital, Groby Road, University Hospitals of Leicester NHS Trust, Leicester, UK
[3]Leicester General Hospital, NIHR Leicester Biomedical Research Centre, Leicester, UK
[4]Leicester Royal Infirmary, Infirmary Square, University Hospitals of Leicester NHS Trust, Leicester, UK
[5]SAPPHIRE Group, Health Sciences, University of Leicester, Leicester, UK
[6]Paediatric Emergency Medicine Leicester Academic (PEMLA) Group, Children's Emergency Department, Leicester Royal Infirmary, Leicester, UK
[7]Leicester Children's Hospital, Leicester Royal Infirmary, Infirmary Square, University Hospitals of Leicester NHS Trust, Leicester, UK
[8]NIHR Health Protection Research Unit in Environmental Exposures and Health, University of Leicester, Leicester, UK

X Sarah Diver @sarah_diver and Damian Roland @damian_roland

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Contributors SD and LC conceived the analysis. SD led the clinical service evaluation with RHG, collected and analysed the clinical data and wrote the manuscript. FS, JS and LC collected and analysed environmental data. HL and GW (adult) and DR and EAG (paediatric) provided hospital attendance and admission data. AH and CB were involved in data interpretation and manuscript design. LC is the guarantor and is responsible for the integrity of the data and the final decision to submit. All authors contributed to data interpretation and writing of the manuscript and have approved the final version for submission.

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Patient consent for publication Not applicable.

Ethics approval This study involves human participants. Anonymised data were collected in the context of a retrospective service evaluation (as per the University Hospitals of Leicester NHS Trust Clinical Audit and Quality Improvement Policy; project registration number 13263) and, therefore ethical approval was not required. Informed consent was not required as data were anonymised prior to evaluation.

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ORCID iDs
Sarah Diver http://orcid.org/0000-0002-5803-5121
Gerrit Woltmann http://orcid.org/0000-0002-9253-6034
Damian Roland http://orcid.org/0000-0001-9334-5144

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