Feeling it in your bones: association between rain and joint or back pain

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Objective To study the relation between rainfall and outpatient visits for joint or back pain.

Design Observational study.

Setting US Medicare insurance claims data linked to rainfall data from US weather stations.

Participants 1 552 842 adults aged ≥65 years attending a total of 11 673 392 outpatient visits with a general internist during 2008-12.

Main outcome measures The proportion of outpatient visits for joint or back pain related conditions (rheumatoid arthritis, osteoarthritis, spondylosis, intervertebral disc disorders, and other non-traumatic joint disorders) was compared between rainy days and non-rainy days, adjusting for patient characteristics, chronic conditions, and geographical fixed effects.

Results Of 11 673 392 outpatient visits by Medicare beneficiaries, 2 095 761 (18.0%) occurred on rainy days. In unadjusted and adjusted analyses, the difference in the proportion of patients with joint or back pain between rainy days and days without rain was significant (unadjusted, 6.23% v 6.42% of visits, P<0.001; adjusted, 6.35% v 6.39%, P=0.05), but the difference was in the opposite to the anticipated direction and was so small that it is unlikely to be clinically meaningful. No statistically significant relation was found between the proportion of claims for joint or back pain and the number of rainy days in the week of the outpatient visit.

Conclusion In a large analysis of older Americans insured by Medicare, no relation was found between rainfall and outpatient visits for joint or back pain.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- Many people believe that changes in weather conditions—including increases in humidity, rainfall, or barometric pressure—worsen symptoms of joint or back pain
- Several studies exploring the relation between weather patterns and joint pain have reached mixed conclusions
- Although studies have explored a variety of weather conditions and used detailed measures of joint pain, these have been survey based and included small numbers of patients

WHAT THIS STUDY ADDS

- Data on millions of outpatient visits of older Americans linked to data on daily rainfall showed no clinically meaningful relation between daily rainfall and outpatient visits for joint or back pain
- No statistically significant relation was found between the proportion of claims for joint or back pain in any given week and weekly rainfall

Introduction

Many people believe that weather conditions, such as rain or barometric pressure, worsen joint or back pain, particularly among those with arthritis. Although previous studies have explored a variety of weather conditions and used detailed measures of joint pain, they were survey based, included small numbers of participants, and had mixed conclusions. We used data on millions of outpatient visits of older Americans, linked to data on daily rainfall, to analyse the relation between rain and outpatient visits for joint or back pain.

Methods

Our study combined two datasets: outpatient visits for joint or back pain among Medicare beneficiaries, and information on daily rainfall by zip code. For information on outpatient visits, we used the 2008-2012 US Medicare 20% Carrier Files. These data include diagnosis codes, place of treatment, and patients’ personal characteristics and chronic conditions. We identified all patients aged at least 65 years who saw a general internist during 2008-2012.

The Global Historical Climatology Network Daily database provided information on rain, which included daily precipitation measurements from 3257 US weather stations.

To combine the datasets, we identified the latitude and longitude of the centroid of each patient’s zip code and matched to the nearest weather station (<30 miles of zip code).

Identification of pain episodes

We identified outpatient visits according to Healthcare Common Procedure Coding System codes for joint or back pain.
allowing for appointments with internists that were booked within a few days of a rainy day if not on the day itself.

Classification of precipitation
To measure precipitation, we generated an indicator variable for whether rainfall exceeded 2.54 mm in an individual’s zip code on the day of consultation, and we identified the week of an outpatient visit and generated indicators for the number of days that week the weather station recorded any precipitation. In addition to these measures we also considered continuous measures (millimetres) of daily or weekly rainfall.

Statistical analysis
We estimated a visit level multivariable linear probability model of whether an outpatient visit concerned a joint or back pain related condition (binary variable), as a function of precipitation on the day of the visit (binary variable or continuous measurement). We also estimated a visit level multivariable linear probability model of joint or back pain as a function of the number of days with precipitation during the calendar week of the outpatient visit (and in a separate model, millimetres of rainfall in the week).

We conducted two analyses to account for the difficulty in booking an appointment on the first day of symptoms. For full details, see bmj.com.

Results
Overall, 2 095 761 of 11 673 392 (18.0%) outpatient visits by Medicare beneficiaries during 2008-12 occurred on rainy days. Patient characteristics were similar between rainy and non-rainy days, with small statistically significant differences in absolute terms (see table 1 on bmj.com).

In unadjusted and adjusted analyses, there was a statistically significant difference in the proportion of patients with diagnoses for joint or back pain between rainy days and non-rainy days (unadjusted: 6.23% (95% confidence interval 6.20% to 6.26%) vs 6.42% (6.40% to 6.43%), P=0.001; adjusted: 6.35% (6.32% to 6.39%) vs 6.39% (6.38% to 6.40%), P=0.05, adjusted difference 0.04% (95% confidence interval −0.07% to 0.001%) (fig 1).

The differences were in the opposite to the anticipated direction, however, and were so small that they are unlikely to be clinically meaningful. We found no statistically significant relation when daily rainfall was modeled as a continuous measure.

We also found no relation between the proportion of claims for joint or back pain and the number of rainy days in the week of the outpatient visit (see fig 2 on bmj.com). There was also no statistically significant relation between the proportion of joint or back pain related visits in any given week and weekly rainfall (modelled as a continuous measure) during that week or the preceding week.

Discussion
In an analysis of millions of outpatient visits of older Americans (≥65 years) during 2008-12, the proportion of joint or back pain related visits was not associated with rainfall on the day of the appointment or with the amount of rainfall during that week or the preceding week.

Studies of this association have benefited from detailed measurements of pain severity but have been limited by small sample sizes and recall and confirmation bias in surveys.1 5 We assumed that if symptoms were substantial they might prompt at least a small (but statistically identifiable) increase in the likelihood that patients would report them to their physician and that physicians would in turn bill Medicare.

Limitations of this study
We lacked detail on disease severity to definitively exclude higher rates of rainfall related joint or back pain, and we lacked information on use of drugs during periods of pain exacerbation; patients could self manage symptoms with analgesics.

We also relied on administrative data, which are primarily focused on conditions rather than symptoms, which means that patients with joint or back pain related conditions who saw their physician for an unrelated symptom may have administrative diagnosis codes for both conditions. Our approach, however, assumed that a small but statistically identifiable relative increase in joint or back pain may still occur during rain compared with no rain.

Finally, we focused on older patients and studied rainfall specifically, rather than other weather conditions such as barometric pressure.

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Individual differences in normal body temperature

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**Objective** To estimate individual level body temperature and to correlate it with other measures of physiology and health.

**Design** Observational cohort study.

**Setting** Outpatient clinics of a large academic hospital, 2009-14.

**Participants** 35 488 patients who neither had a diagnosis of infections nor were prescribed antibiotics, in whom temperature was expected to be within normal limits.

**Main outcome measures** Baseline temperatures at individual level, estimated using random effects regression and controlling for ambient conditions at the time of measurement, body site, and time factors. Baseline temperatures were correlated with demographics, medical comorbidities, vital signs, and subsequent one year mortality.

**Results** In a diverse cohort of 35 488 patients (mean age 52.9 years, 64% women, 41% non-white race) with 243 506 temperature measurements, mean temperature was 36.6°C (95% range 35.7-37.3°C, 99% range 35.3-37.7°C). Several demographic factors were linked to individual level temperature, with older people the coolest (−0.021°C for every decade, P<0.001) and African-American women the hottest (versus white men: 0.052°C, P=0.001). Several comorbidities were linked to lower temperature (eg, hypothyroidism: −0.013°C, P=0.01) or higher temperature (eg, cancer: 0.020, P<0.001), as were physiological measurements (eg, body mass index: 0.002 per m/kg, P<0.001). Overall, measured factors collectively explained only 8.2% of individual temperature variation. Despite this, unexplained temperature variation was a significant predictor of subsequent mortality: controlling for all measured factors, an increase of 0.149°C (1 SD of individual temperature in the data) was linked to 8.4% higher one year mortality (P=0.014).

**Conclusions** Individuals’ baseline temperatures showed meaningful variation that was not due solely to measurement error or environmental factors. Baseline temperatures correlated with demographics, comorbid conditions, and physiology, but these factors explained only a small part of individual temperature variation. Unexplained variation in baseline temperature, however, strongly predicted mortality.

**Introduction**

Comparing a patient’s temperature to the population average allows clinicians to diagnose acute pathological states, from infections to thyroid disorders. But just as measuring the absolute temperature in a room would not be used to infer how warm or cold an individual felt, should absolute body temperature be used to infer an individual’s physiological state? After all, deviations from the population average can be related to individual physiology, such as age and circadian metabolic cycles. As these factors vary across individuals, it is possible that individual temperatures differ from the population average. We estimated baseline temperatures for individual patients and explored links with demographics, physiological measures, and mortality.

**Methods**

We used a dataset of electronic health records from a large US based academic hospital. The study cohort included patients with one or more routine visits to the hospital’s emergency and outpatient departments from 2009-14 during which temperature was measured.

**Statistical analysis**

We correlated individual temperature random effects with other variables of interest in the electronic health record: demographics; comorbidities, defined using ICD-9 codes over the year before visits; and physiological measurements, using average values over the period spanning from first to last included visit date for each patient.

We explored the relation between individual temperature and mortality, using linkage to state social security data. For full details of the statistical analysis, see bmj.com.

**Results**

Of 374 306 patients with temperature measurements at outpatient visits, we excluded 13 0800 (infection diagnoses or antibiotic prescriptions), leaving 243 506 visits. The mean age of the sample was 52.9 years, 64% were women, and 41% were non-white. The mean temperature was 36.6°C (95% confidence interval 36.6°C to 36.6°C) and each patient had a median number of 5 (interquartile range 3-9) temperature measurements over a median of 2.1 (0.8-3.8) years.

The main measurement sites were oral (88.2%), temporal (3.5%), tympanic (3.0%), and axillary (0.1%). Temporal, tympanic, and axillary temperatures

**WHAT IS ALREADY KNOWN ON THIS TOPIC**

- A long tradition of research on human core body temperature, starting in the 19th century, has focused on establishing average temperature in a population
- Temperature is known to be influenced by many factors that differ widely across patients (eg, age, circadian, metabolic, and ovulatory cycles) raising the possibility that individual baseline body temperatures might vary systematically

**WHAT THIS STUDY ADDS**

- Individual baseline temperatures are correlated with specific demographic factors, with older people the coldest and African-American women the hottest
- Particular medical conditions were also statistically significantly linked to lower or higher temperature, as were physiological measurements, but these factors explained only 8.2% of variation in individual baseline temperatures
- The remaining unexplained variation was a large and significant predictor of subsequent mortality, nearly 8.4% higher mortality for a 1 SD increase in temperature
were significantly lower than oral temperatures (by −0.032°C, −0.060°C, and −0.264°C, respectively; all P<0.001). We observed diurnal variation by hour, with a peak at 4 pm (0.034°C v 12 pm, P<0.001). Higher ambient temperature and dew point were both linked to higher body temperature. On a median temperature day in our dataset (12.2°C), body temperature was on average 0.075°C lower in July than in February.

Baseline temperatures declined with age (−0.021°C every decade, P<0.001). African-American women had the highest temperature (0.052°C higher than white men, P<0.001). Baseline temperature also varied significantly as a function of comorbid conditions. Cancer was linked to higher temperature (0.020°C, P<0.001), whereas hypothyroidism was linked to lower temperature (−0.013°C, P=0.01). The total number of comorbidities was not statistically significantly linked to baseline temperature over and above all individual comorbidities.

Controlling for demographic factors and comorbidities, higher temperatures were linked to increased body mass index (0.002°C per kg/m², P<0.001), higher pulse (6.0×10⁻⁵°C per bpm, P=0.17), and increased diastolic blood pressure (1.2×10⁻⁶°C per mm Hg, P=0.01). The figure shows mean vital signs over the study period and their relation to baseline temperatures by sex.

Controlling for age, sex, race, vital signs, and comorbidities, a 1°C increase in temperature translated into 3.5% higher mortality those related to metabolism and obesity. These differences may arise from obvious thermodynamic factors: bodies with larger mass dissipate heat less rapidly, leading to higher temperatures. Fat (which is correlated with mass) could also act as an insulator, leading to higher heat retention in people with more fat. It is well known that caloric restriction through fasting leads to down-regulation of temperature, presumably to conserve energy. The existing literature of caloric supplementation suggests that the ability of individuals to dissipate excess energy from overfeeding varies widely.

Given the strong links between resting metabolic rate and body temperature, a higher resting temperature could be a response to dissipate excess energy from caloric intake. We found that a raised temperature correlated with body mass index and activation of the sympathetic nervous system (increased pulse rate and diastolic blood pressure).

We found a large correlation between individual temperature and mortality that was not explained by measured patient characteristics. We did identify a correlation between diagnosed cancers and temperature; subclinical infections or rheumatological diseases could exert a similar effect. If higher temperature reflected undiagnosed cancers or other illnesses, this would generate the correlation we observed between the unexplained component of temperature variation and subsequent mortality from these same illnesses.

The finding that measured temperature was lower in hot months and higher in cold months may reflect engagement of well known compensatory adaptations (eg, evaporative cooling) to temperatures experienced over longer periods, as opposed to the short term direct effects of higher or lower temperature.

Finally, our estimate of population mean temperature differed from other studies—lower than in a sample of primarily young, healthy participants, and higher than in a population of older adults in healthcare settings. One potential advantage of our approach is that it adjusted for environmental and temporal factors at the time of measurement, which was not possible by other studies.

**Limitations of this study**

We considered patients at one academic centre and measured temperature using similar equipment, which can have correlated errors in measurement. Our data came from one climate zone; although we controlled for the substantial variation in environmental conditions within this zone, temperature and compensatory mechanisms may vary across climatic zones.

We excluded patients with infection and those prescribed antibiotics, but it is possible that some patients had undiagnosed and untreated infections. However, since this would have to be a consistent finding over multiple visits for the same patients, and since most infections are by contrast transient, this is unlikely to have affected our estimated correlation between individual baseline temperature and mortality.

We sampled patients based on visits to a hospital emergency department and clinics. This resulted in an ethnically and medically diverse sample over multiple years of data, but it also selected patients with a higher comorbidity burden and mortality than in the general population. An advantage is that our sample was representative of the population of patients using healthcare today.

**Discussion**

Individuals have body temperature set points that correlate with a range of demographic factors, comorbid conditions, and physiological measurements, particularly...
Visitors to London’s Great Ormond Street Hospital may be in for a lovely surprise. Those who venture past the Peter Pan statue at the entrance, through the busy corridors, will eventually discover a little garden, secreted away from the ward bustle. Built on an abandoned boilerhouse roof, it is now a peaceful, sheltered retreat. It is surrounded by shrubbery, with an open wooden pavilion at one end. It is overlooked by hospital wards, but when you stand in the middle the hospital vanishes.

What may be a surprise today was more the norm in the past: Florence Nightingale was a champion of outdoor spaces, and in the 19th century, hospital gardens were an important part of the therapeutic regimen. It was only after the second world war, and the birth of the NHS, that they began to disappear. Hospitals, built for clinical effectiveness, had to house numerous specialist units and provide ever more parking spaces. The cost of managing gardens was hard to justify, and they were easy to dismiss. Now, they are making a comeback.

Horatio’s Garden
Horatio’s Garden is perhaps one of the best known hospital gardens. Horatio Chapple had the idea when he was volunteering at the Duke of Cornwall spinal treatment centre at Salisbury District Hospital.

Wondering at the lack of outdoor space for patients, he decided to conduct some research. He found that patients wanted a change from the clinical environment—somewhere “beautiful,” with colour, flowers, wildlife, and running water, where they could temporarily return to “normal life.” Staff, on the other hand, thought the garden should be a “rehabilitation tool,” with different surfaces, slopes, curves, and steps to help patients recovering from spinal injuries practise moving with walking aids or in wheelchairs.

In August 2011 Horatio was killed by a polar bear while on expedition in Norway. His parents, both doctors, decided to make his vision a reality. They focused on the patients’ wishes and built an accessible garden with space and privacy, where patients could come to terms with often life changing injuries. Now many patients take their first steps outside here.

The garden is full of hardy perennials, giving it colour all year. It also gives inpatients a sense of the seasons—something that can be lost inside a clinical ward. Patients report that the garden helps to them feel that they are making progress.

It gives them a space to reflect, a sense of community, and a support network with those facing similar challenges. Doctors have noticed that the ward atmosphere has become calmer since the garden opened. Many patients said it restored their sense of identity—according to one: “You can see the earth, and you can see sky overhead, and just all these things are so much part of the life I had before.”

This success has led to a second Horatio’s Garden being built in Glasgow, another one under way at Stoke Mandeville Hospital, in Buckinghamshire, and a further two are at the fundraising stage.

Aberdeen Royal Infirmary
Unlike other hospital gardens, Aberdeen Royal Infirmary’s roof garden is officially designated as clinical space.

Before it was built, the only green space was outside the front entrance. The roof garden is open 24 hours a day and floodlit after dark. Staff can take a fully ventilated intensive care patient there, with full resuscitation and monitoring equipment. A
sanctuary alongside the garden features a large panoramic window, so that in poor weather, patients can still look out.

Rev James Falconer, healthcare chaplain at the hospital for 25 years and one of the driving forces behind the garden, says that for patients the garden “can make a significant difference in recovery and sense of wellbeing.” One patient told him: “It is the one thing that keeps me going.”

Staff have noticed that, after time in the garden, patients may work more positively with physiotherapists, for example, and are more engaged with their care.

The garden was noted as an area of good practice and a valuable resource for patients receiving extracorporeal membrane oxygenation treatment in a recent NHS England review.

Wansbeck Hospital

The therapeutic benefits of hospital gardens are just as valuable for patients' visitors. The Oasis at Wansbeck Hospital—built in 2010—was one of the first places to recognise this. It is not only a garden but includes a separate suite of rooms for families of patients receiving end of life care.

The Oasis is designed to feel like a living space that opens out onto a garden. It has proved so popular that other hospitals in Northumbria NHS Trust have replicated the idea.

St Margaret's, Epping

Strong evidence suggests gardens are therapeutic for patients with dementia. Sarah Croot, a consultant occupational therapist specialising in dementia and frailty services, described how she uses gardening at St Margaret’s Hospital, Epping.

She says that gardening can have a tremendous impact on patients. This is particularly true for those with dementia, even when it is quite advanced, as gardening can trigger old memories and skills.

Patients are “now in the role of working in the garden,” and grow fruit and vegetables that they eat in the hospital. The garden also provides an element of sensory stimulation—with different sounds, perfumes, and textures—and a pleasurable environment.

Funding

What these gardens have in common is that they are charitably or privately funded. They were built and are maintained thanks to the energy and resourcefulness of volunteers.

To fund Horatio’s Garden, “a lot of cupcakes were sold, and marathons run,” said Victoria Holton, the garden’s executive trustee. “No one is going to spend money on a garden when we need an x ray machine,” said Fraser Smith, consultant general and colorectal surgeon at Royal Liverpool University Hospital and garden enthusiast.

Scarce NHS funds are rightly focused on clinical needs. Nevertheless, gardens are increasingly recognised as a valuable resource. The King’s Fund recently set out “a wide range of recommendations that we believe will help to integrate the benefits of gardens into the mainstream of health policy,” and clinical commissioning groups are prescribing gardening to patients, as they believe it can save money in the long run.

Crucially, however, if we want to continue to build gardens, we need space. The Naylor report outlined plans to sell off NHS land to raise money to invest in patient care. The gardens discussed here were built on rooftops, in small spaces, or on previously unused land—that may be a prime opportunity for planners.

The benefits of gardens are not limited to patients. Some hospitals, such as Great Ormond Street, already have gardens that are designated for staff, and the Royal Aberdeen Infirmary is looking to build a staff garden. Gardens and gardening are also being included in community care. The Lambeth GP Food Co-op has set up 11 food growing gardens in GP surgeries and in King’s College Hospital, that are run by patients, healthcare workers, and volunteers.

The evidence for the benefits of hospital gardens is incontrovertible. Should we learn from the past to take us into the future?

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A PATIENT'S PERSPECTIVE

Lyn Farrugia’s 12 year old daughter, Gabriella, is being treated at Great Ormond Street Hospital for juvenile dermatomyositis

Before the garden opened

“When Gabriella was first admitted (and for several weeks after), I was in a state of complete shock. I couldn’t leave her at the beginning because she was too ill, but then, even when she was in physio and school, I didn’t feel able to leave the hospital—nothing felt safe. The furthest I got to outside was to sit by the Peter Pan statue right outside the front entrance. When I eventually did venture out, I realised the seasons had changed, and I had missed it. To have had a garden within the hospital would have allowed me to still be close to Gabriella, but to have been able to feel the sun on my face or the rain on my skin—things that make you feel alive, but that you completely take for granted.

“Where we stayed in the oldest part of the hospital there was no communal area for parents. You see each other in the kitchen and talk over a snatched cup of tea. This is fine, but when times are hard and you want to cry, scream, be angry, there is nowhere to go. A garden would have given me somewhere to go, when I needed time out.

“There were times when I didn’t want to be in the real world and watch everyone going about their normal lives, when our lives had been so traumatised. I missed the smells of being outside, watching the birds listening to the wind. A tranquil space, where you can just ‘be’ and not have to make any decisions or think about anything is very rare in hospital, and it is probably the thing you need most.”

Since the garden opened

“The Morgan Stanley Garden has made such a difference to my daughter and myself. We now come to GOSH every month, for two days of infusions. Gabriella can leave the ward room for an hour of physio and then she is back on a bed, having six hours of drug infusions, where she can’t move at all.

“We don’t have a chance to leave the hospital, but my daughter always asks to sit in the garden before treatment. It is a really important part of her GOSH stay now, the ability to just sit somewhere so tranquil and beautiful which is only one minute from our ward.

“When Gabriella is in physio, I sit in the garden, absorbing the serenity. You can’t hear any hospital noises, and you can remember what the real world is like. It sounds over dramatic, but when your life revolves around hospital visits and medication, that sense of normality is desperately needed.”
Objective To test whether a full moon contributes to motorcycle related deaths.

Design Population based double control analysis.

Setting Nighttime (4 pm to 8 am), United States.

Participants 13 029 motorcycle fatalities throughout the United States, 1975 to 2014.

Main outcome measure Motorcycle fatalities during a full moon.

Results 13 029 motorcyclists were in fatal crashes during 1482 relevant nights. The typical motorcyclist was a middle aged (mean age 32 years) man who was not wearing a helmet. 4494 fatal crashes occurred on 494 nights with a full moon (9.10/night) and 8535 on 988 control nights without a full moon (8.64/night). Comparisons yielded a relative risk of 1.05 associated with the full moon (95% confidence interval 1.02 to 1.09), a conditional odds ratio of 1.26 (95% confidence interval 1.17 to 1.37), and an increased risk of fatal motorcycle crashes, although potential confounders cannot be excluded. An awareness of the risk might encourage motorcyclists to ride with extra care during a full moon and, more generally, to appreciate the power of seemingly minor distractions at all times.

Introduction Motorcycle crashes in the US account for nearly 5000 deaths annually—about one in seven road traffic fatalities. The three features most likely to cause distraction are large size, bright luminance, and abrupt onset, all of which apply to the full moon. We hypothesised that as people’s attention is drawn to a full moon, it might contribute to fatal motorcycle crashes.

Methods We obtained road safety data from the US National Highway Traffic Safety Administration. These data were accrued from the Fatality Analysis Reporting System, the registry of fatal crashes involving a motor vehicle in the US. The database encompasses only fatal crashes and lacks data on driver education, training, speed, direction, congestion, and travel distances. We included all years from 1 January 1975 (inception of database) to 31 December 2014 (most recent update). For details of the statistical analysis, see bmj.com.

Selection criteria The specific database codes for fatal motorcycle crashes in the Fatality Analysis Reporting System evolved over time and we identified the corresponding vehicle type for each year. The reporting system provided data on the motorcyclist (age, sex, seating position, helmet use), vehicle (style, vintage, engine size), environment (location, century, season, weekday), and crash (vehicle count, impact location, object mobility).

We defined the full moon as the night when the entire facing surface was illuminated, as viewed from Earth, and nighttime as 4

Cumulative count of excess fatalities on full moon nights compared with control nights

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pm to 8 am to include hours when the full moon might be visible. Each full moon was further classified as a supermoon or a regular full moon.\textsuperscript{29} A supermoon is observed during perigee (when Earth and Moon are about 50,000 km closer), when brightness is increased by 30%.\textsuperscript{30}

We defined controls as the night one week before and one week after the full moon.

Results
Overall, 13,029 motorcyclists were involved in a fatal motorcycle crash on 494 full moon nights and 988 control nights. The typical motorcyclist was a middle aged man on a street motorcycle with a large engine in a rural location who had a front impact and was not wearing a helmet (table). The distribution of characteristics was similar between full moon nights and control nights.

Overall, 4494 fatal crashes occurred on 494 full moon nights (9.10/night) and 8535 on 988 control nights (8.64/night). Comparisons yielded a relative risk of 1.05 associated with the full moon (95\% confidence interval 1.02 to 1.09), a conditional odds ratio of 1.26 (95\% confidence interval 1.17 to 1.37), and an absolute increase of 226 additional fatal crashes over the study period (figure). The average absolute increase was one additional fatal crash associated with two full moon nights.

Overall, 703 fatal crashes occurred on 65 supermoon nights (10.82/night) and 3791 on 429 full moon nights (8.84/night). The relative risk during a supermoon compared with full moon was 1.22 (95\% confidence interval 1.13 to 1.33) and for 65 supermoon nights compared with 130 control nights was 1.32 (1.20 to 1.45).

Discussion
In this study of motorcycle related deaths in the US over four decades we found that fatalities were more common at night, particularly during a full moon. Although others may have alternative interpretations because observational analyses cannot exclude the possibility of hidden confounding, we believe the findings are not easily explained as artefacts attributable to selection bias, ascertainment bias, reverse causality, fluctuating weather, subjective reporting, or random chance.\textsuperscript{41-45} The findings are also difficult to attribute to confirmation bias, self fulfilling prophecies, social reinforcement, paranormal phenomenon, or geophysical effects.\textsuperscript{46-50} Several aspects of attention and perception could explain an association between the full moon and motorcyle fatalities. A full moon is infrequent and spectacular (it is large and bright against a dark sky, and thus provides a striking contrast of luminance), thereby creating a natural distraction.\textsuperscript{51} It can appear abruptly and tends to rise above the horizon at night, during the hours motorcycle crashes predominate.\textsuperscript{52}

Limitations of this study
We did not analyse automobiles, which have a wider stable base than motorcycles, extensive protection of occupants, and engineering elements that mitigate the risk of death.\textsuperscript{53} We did not explore more complex Fourier statistical models of intermediate lunar phases and positions during other nights.\textsuperscript{54} We tested only one source of inattention whereas a motorcyclist can encounter many distractions and traffic hazards. The shared nature of road traffic means crashes often involve other road users who have differing reasons for travel.\textsuperscript{55}

An additional limitation is the interpretation of the magnitude of the observed association. An average motorcyclist probably spends a small fraction of time gazing at a full moon. Therefore, a net increase in fatal crashes during a full moon should show only a modest magnitude since a large increased risk would be implausible after transient exposure.\textsuperscript{56}

Several other limitations occur because large scale databases lack clinical details and motorcyclists are sometimes non-conformist outliers. The extent of cloud cover, weather, and moon visibility were unknown. Finer analyses of the exact start and end of night were not feasible to account for geographical latitude. Similarly, analyses of the exact interval of moon rise and moon set were not feasible to account for time zone longitude. The speed and direction of the motorcycle at impact were also uncertain. In addition, fallible data entry in government databases can introduce spurious errors.

Conclusion
Extra care is needed when riding a motorcycle during a full moon. Standard safety recommendations to avoid a crash might include maximising visibility, wearing protective clothing, and maintaining the vehicle in excellent condition.\textsuperscript{68-70} Additional strategies while riding include wearing a helmet, activating headlights, scanning the road for defects, respecting the weather, being wary of leaving turning vehicles, obeying traffic laws, and foregoing stunts.\textsuperscript{71-74}
Thunderstorm asthma and demand for emergency medical services

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Objectives To describe the demand for emergency medical assistance during the largest outbreak of thunderstorm asthma reported globally.

Design A time series analysis was conducted of emergency medical service caseload between 1 January 2015 and 31 December 2016. Demand during the thunderstorm asthma event was compared with historical trends for the overall population and across specific subgroups.

Setting Victoria, Australia.

Main outcome measures Number of overall cases attended by emergency medical services and those in patient subgroups.

Results Between 6 pm and midnight on the day of the event, calls for 1326 cases were received, which was 2.5 times higher than expected. A total of 332 patients were assessed by paramedics as having acute respiratory distress, compared with a daily average of 52 during the historical period. After adjustment for temporal trends, thunderstorm asthma was associated with a 42% (95% confidence interval 40% to 44%) increase in overall caseload for the emergency medical service and a 432% increase in emergency medical attendances for acute respiratory distress symptoms. Large increases in demand were seen among patients with a history of asthma and bronchodilator use. The incidence of out-of-hospital cardiac arrest increased by 82% (67% to 99%) and pre-hospital deaths by 41% (29% to 55%).

Conclusions An unprecedented outbreak of thunderstorm asthma was associated with a substantial increase in demand for emergency medical services and pre-hospital cardiac arrest. The health impact of future events may be minimised through use of preventive measures by patients and predictive early warning systems.

WHAT IS ALREADY KNOWN ON THIS SUBJECT

- Thunderstorm asthma is a rare phenomenon whereby a surge in patients with acute respiratory illness occurs after a thunderstorm.
- It increases pressure on health services such as primary care facilities and emergency departments.

WHAT THIS STUDY ADDS

- Thunderstorm asthma was associated with a 42% increase in overall caseload of emergency medical services and a 432% increase in emergency attendances for acute respiratory distress symptoms after adjustment for temporal trends.
- Demand management strategies were insufficient to manage such a widespread and rapid onset event, with ambulance resources quickly depleted.
- The incidence of out-of-hospital cardiac arrest and pre-hospital deaths increased by 82% and 41%, respectively.

Introduction

Thunderstorm asthma is a rare phenomenon, thought to occur when a source of allergen, typically pollen, and appropriate weather conditions, such as a thunderstorm, combine to trigger severe asthma among susceptible people in the vicinity. On 21 November 2016, parts of Victoria, Australia, encountered a thunderstorm asthma health emergency. The event saw a sudden and unprecedented increase in demand on the emergency medical service and hospital emergency departments. The scale of this event exceeded all previous reports, with approximately 13 000 presentations to hospitals in Victoria, more than 3000 of which were related to respiratory problems.

We describe the demand on Ambulance Victoria, the state-wide emergency medical service in Victoria, Australia, during the 2016 thunderstorm asthma emergency.

Methods

We conducted a retrospective review and time series analysis of the emergency caseload in Victoria, Australia, between 1 January 2015 and 31 December 2016.

Victoria has a population of 6.07 million and spans almost 92 000 square miles. Its capital, Melbourne, sees an average of 10 thunderstorms a year. On 21 November 2016 Victoria activated elements of its health emergency response plan and implemented escalation processes. Ambulance Victoria stopped its usual secondary triage processes. Operational paramedics were permitted to complete paper rather than electronic patient care records.

We estimated the 99th centile of cases over the two year study period using linear interpolation. We compared groups using the x², Fischer’s exact, t test, or Mann-Whitney U test, as appropriate. We compared the baseline characteristics of patients seen by Ambulance Victoria during the thunderstorm asthma event (6 pm to 11:59 pm on 21 November 2016) with those seen during the same hours on the three previous consecutive Mondays.

To investigate the effect of thunderstorm asthma on daily caseload of Ambulance Victoria after adjustment for temporal trends, we used negative binomial time series regression analyses with distributed lags. We included three lag days in models to assess residual effects. We conducted time series analyses across patient subgroups and local government areas.

Results

Figure 1 shows the hourly emergency caseload, with a sharp increase after the storm and wind change. Between 7 pm and 8 pm, the caseload reached 297 cases, corresponding to 2.43 times the 99th centile caseload of the two year study period (122 cases). Between 6 pm and midnight, emergency services received calls for 1326 cases, which was 2.50 times the average (530 cases), equating...
to almost 800 additional cases. The caseload was so extreme that no ambulance could be dispatched to more than 500 cases; these were closed through paramedic telephone assessment. The caseload fell back to 65 cases between 7 am and 8 am the next day, which was under the 99th centile of the comparator period (77 cases).

Almost half of all patients reported a history of asthma, but 26.4% (156 of 590) and 1.4% (8 of 590) were taking only an asthma bronchodilator or preventive medication, respectively. Almost half of the patients seen in the thunderstorm asthma period had acute respiratory distress when assessed by paramedics.

The emergency medical service handled 2954 cases on 21 November and 2493 cases the next day, compared with an average of 1940 cases over the comparator period (see fig 2 on bmj.com). After adjusting for temporal trends, thunderstorm asthma was associated with a 41.7% (95% confidence interval 39.6% to 43.9%) increase in caseload on 21 November. The cumulative effect of the event, accounting for three additional lag days, was an increase in caseload of 103.1% (95.9% to 110.5%) increase in demand from patients using a bronchodilator, compared with 21.3% (14.2% to 28.8%) from patients using preventive medication. Thunderstorm asthma was associated with an 82.2% (67.1% to 98.8%) rise in out-of-hospital cardiac arrests and a 41.4% (28.7% to 55.5%) rise in pre-hospital deaths.

Discussion

The world’s largest recorded and most severe thunderstorm asthma health emergency was associated with a 41.7% increase in emergency service cases and a dramatic rise in cases of acute respiratory distress.

We found a 2.5-fold increase in demand for emergency medical services between 6 pm and midnight on the day of the event. Such unprecedented demand place enormous strain on health services. In Victoria, the emergency medical services implemented a range of demand management strategies, but the extent, severity, and duration of this event surpassed all expectations. The current health emergency response plan was drafted for events such as bushfires, heatwaves, and mass casualty events. It was unlikely to be effective for a complex emergency such as thunderstorm asthma, given its broad geographical spread and rapid onset. Warning of this event may have enabled earlier implementation of demand management strategies, allowing a more streamlined response and a reduction in the wider impact.

The health impact might also have been reduced through patients’ use of preventive measures. We found that demand by patients taking preventive medication increased by only 21.3%, compared with a 103.1% increase among patients taking asthma bronchodilators only.

Finally, we observed a near doubling in cardiac arrests on the day of the event, with the majority reported to be due to a respiratory cause. Ten deaths have been attributed to thunderstorm asthma. Increases in outdoor air pollution in our region have been associated with an increased risk of out-of-hospital cardiac arrests.

Our study was retrospective. The capture of patient medications and pre-existing conditions was dependent on this information being entered into patient care records and may be under-reported. Because of the high demand for emergency services, only 82.3% of cases had an electronic patient care record available, and numbers for subgroup analyses may be under-reported. We were unable to confirm the patients’ hospital diagnoses. Nevertheless, our study is strengthened by the large historical sample over a two year period.

Early warning systems may ensure that susceptible people are alerted and help to minimise the health impact of future emergencies.