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Severe weather warnings predict fracture epidemics

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Winter epidemics of fractures have been described that greatly exceed normal seasonal variations and overwhelm resources. We investigated the relationship between severe weather warnings, the frequency of fractures, and fracture related workload.

There was a significant increase in fractures with cold and inclement weather, mostly low-energy fractures treated with day-case surgery or in fracture clinics. The number of patients treated as inpatients for fractures did not increase. Hip fractures were not associated with weather. Severe weather warnings for icy roads were predictive of fracture epidemics (p < 0.01) with an associated 40% (95% confidence limits 20–52%) increase in fractures. Meteorological Office issued severe weather warnings can provide a trigger to plan for an increased workload of low-energy fractures, with opportunities for anticipatory public health measures.

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Introduction

There is an increase in accidents during periods of snow and ice. Winter epidemics of fractures have been described that greatly exceed normal seasonal variations and overwhelm resources. Such increased workload is equivalent to a 'major accident' or 'moderate disaster'. Distinct patterns of injury associated with ice and snow are recognised. Whilst media attention highlights traffic accidents, the risk of falls is often overlooked.

Despite the significant implications for healthcare planning, the magnitude of such 'epidemics' are generally not appreciated. Extreme weather has the potential not only to increase numbers of casualties but also decrease the ability of health services to treat them.

Weather warnings can be used in health promotion, and can be communicated to patients with chronic obstructive pulmonary disease to take precautions to prevent a chest infection, and to manage fluctuations in health care demand. The relationship between weather variables and inpatient admissions to specialist trauma units has been well documented, as has the seasonality of hip fractures. However, the relationship between official severe weather warnings, weather variables and patients with fractures presenting to emergency departments and minor injury units has not been assessed. Such information would enable prediction of fracture epidemics, and trigger planning. We set out to demonstrate an association between increased fracture related workload and inclement recorded weather variables and official severe weather warnings.

Patients and methods

We identified all patients presenting with fractures to two adult and one paediatric accident and emergency departments and a minor injuries unit covering a combined population of 778,367 in Edinburgh (United Kingdom) over a 2-month winter period. Data for two consecutive years were collected from electronic case notes completed by the responsible clinician at the time of treatment (December 2008–January 2009, and December 2009–January 2010).

We obtained the number of emergency operations performed for fractures and the number of operating theatres utilised at all sites from theatre records. The number of elective procedures cancelled was obtained from data collected prospectively by hospital management.

Meteorological data

Daily objective measurements of maximum, minimum and grass (ground) temperature, and subjective assessment of the 'state of ground' were obtained from the meteorological team at the Royal Botanic Gardens of Edinburgh, an official observing site for the Meteorological Office.

All official Severe Weather Warnings issued during the study period for the Edinburgh area were obtained from the Meteorological Office. Severe weather warnings are issued based on an algorithm that takes into account a number of predicted weather variables.

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Predicted temperature, precipitation and recent state of the ground measurements are taken into consideration in ‘icy road’ warnings.

**Statistical analysis**

All data were analysed on SPSS for Windows v16 (SPSS Inc., Chicago, IL). Pearson correlation was used for correlations. Multiple linear regression was used to test for the effects of admissions adjusted for festive periods (Christmas eve, Christmas day, New Years eve and New Years day). A p-value of <0.05 was considered statistically significant. Confidence limits for percent increase in fractures on days with icy road weather warnings were calculated by taking logarithms of the numbers of fractures and carrying out a t-test.

**Results**

**Fractures and fracture related workload**

The total number of hospital attendances remained equal for both periods of study although there was a significant increase in fractures in December 2009 and January 2010. The figures for all emergency attendances, fractures, fracture related admissions and theatre usage are summarised in Table 1. The number of trauma operations, and theatre being utilised for trauma increased during this period. However, the number of patients treated as inpatients for fractures did not increase. The remainder were treated by day-case surgery or as outpatients. Fewer elective procedures were cancelled in the latter period of study.

**Meteorological data**

December 2009–January 2010 was significantly colder (mean maximum air temperature and mean grass temperature) and had four times as many warnings for severe weather than the same period the previous year. The vast majority of these warnings were for icy roads. The meteorological data are summarised in Table 2.

**Correlation between weather and workload**

Overall number of emergency attendances correlated poorly with recorded weather variables and weather warnings (Table 3). Fractures and fracture related admissions were significantly associated with minimum and maximum air temperature in December 2009–January 2010, although this relationship was not apparent the previous year. Over the entire study period, days for which severe weather warnings for icy roads had been issued were significantly associated with both fracture presentations and admissions. There was a 40% (95% confidence limits 20–52%) increase in fractures on days with weather warnings for icy roads. The results were not explained by any coincidental festive season effects. There was no significant correlation between any weather variable and the number of patients with hip fractures. The relationship between ground temperature, weather warnings, all emergency attendances and fracture attendances at Emergency Departments and Minor Injuries Units are shown in Figs. 1 and 2.

In 2008/2009 there was a significant correlation between weather warnings for icy roads and both the number of operations undertaken (Pearson correlation 0.45, p < 0.001) and theatres utilised (Pearson correlation 0.23, p < 0.01). A significant correlation was also apparent for operations undertaken (Pearson correlation 0.41, p < 0.01) and theatres utilised (Pearson correlation 0.35, p < 0.01) lagged 1 day behind the weather warning. Festive periods (Christmas and New Year) were only associated with fracture presentations and admissions at New Year, 2009/10.

**Discussion**

Although overall attendances to emergency departments and minor injury units remained constant, there was a significant increase in attendances with fractures in cold and inclement weather.
weather. In addition to an increase in environment related injuries, this may reflect a reduction in ‘non-urgent’ attendances at emergency departments during periods of extreme weather.

Conflicting correlations between trauma admissions and weather variables have previously been published.\(^1,2,14\) However, admission to hospital is only necessary in a minority of fracture patients, and is therefore not a true representation of workload. It is recognised that periods of ice and snow are associated with a significant increase in ‘walking wounded’ patients, who have fractures affecting the upper limb and ankle.\(^14,21,23\) These fractures are commonly treated by day-case surgery, or non-operatively in fracture clinics. Whilst periods with cold temperatures and inclement weather were associated with an overall increase in trauma operations and theatres utilised in our series, the number of patients being admitted did not.

The incidence of hip fractures was not associated with meteorological variables in our series. This may reflect a change in the demographic of patients treated at this time. Elderly patients at greater risk of fragility fractures may be forced to stay indoors during icy periods, with younger patients spending relatively more time exposed to the adverse conditions. Previous studies have demonstrated seasonal increases in hip fracture incidence\(^7,12,13,15,18,24\) although there have been conflicting reports of the impact of meteorological conditions.\(^1,5,7,11–13,15,18,24\) Freezing rain,\(^13\) cold temperature,\(^6,12,13,18\) and wind\(^18,24\) have all been implicated in the increased incidence of hip fractures during winter. The range of cold temperatures within our series may have not been sufficiently wide to demonstrate an association. We compared two periods of low temperatures, which may have been below the threshold where significant differences resulting from temperature may be evident.

Over the entire study period there was a strong correlation between severe weather warnings for icy roads and both fracture presentations and fracture related admissions. This statistically significant and clinically important relationship has never previously been demonstrated. It was independent of the expected rise in presentations and admissions over the festive periods of Christmas and New Year. A severe weather warning for icy roads is likely to also indicate icy pavements. We report a significant increase in the number of walking wounded, predominantly resulting from low energy slips and falls rather than high energy road traffic accidents. This highlights the importance of ensuring
pavements are clear of ice, in addition to roads, during periods of extreme weather.

We demonstrated a relationship between weather warnings and both the number of operations undertaken in our trauma department and theatres utilised in December 2008–January 2009, but this correlation was not evident the following year. Winter 2009/2010 was particularly extreme, with a number of sustained periods of icy weather. The backlog of fractures may take weeks to clear, with many treated on a semi-urgent basis (within 2 weeks). Therefore associations between theatre activity and daily weather variables must be interpreted with caution.

The strengths of this study include capture of all patients presenting with fractures to emergency departments and minor injuries units over an entire NHS region. Routine clinical data was recorded by staff directly assessing and treating patients. Weather information was recorded at an official Meteorological Office observing site. The study of consecutive years reduced confounding factors on the frequency of fractures due to seasonality, whilst the festive period as a possible confounding factor was also specifically addressed. However, the relatively short study period may preclude generalisability, and other possible confounders contributing to fracture burden such as an increase in steroid use in COPD sufferers were not explored. A wider multicentre study with an increased study period that specifically analyses the underlying cause of each attendance is required.

Historically there has been huge investment in preparing for predicted high profile epidemics or disasters such as H1N1 and severe acute respiratory syndrome, based on speculative predictions. Periods of ice and snow do not generate such disaster planning despite recurring patterns of increased fractures and overstretched resources.

The ability of weather warnings to predict fracture epidemics has implications for clinicians and policy makers. Warnings are issued up to 48 h in advance of the inclement weather providing a window of opportunity for public health measures to be implemented and healthcare providers to make preparations. The public can be alerted of the dangers and local authorities can take measures to grit or clear pavements as well as roads. During short periods of icy weather the vulnerable can remain in the safety of their homes but are forced to venture out for essential supplies during more sustained periods. Emergency departments, minor injury and trauma units can ensure adequate stocks of equipment and staff are available. Currently the Meteorological office is piloting an alert sent to hospitals of ‘weather risks of emergency admissions’. These are based on projected admissions, not specific to fractures, and have not been validated.

**Conclusion**

Severe weather warnings predict a statistically significant and clinically important increase in fractures. There is a change in the patterns of injury during icy weather with increasing numbers of low-energy fractures not requiring admission, treated instead as day-case surgery, or in fracture clinics without a significant increase in the number of patients admitted for fractures. This highlights the importance of ensuring pavements are clear of ice, in addition to roads, during periods of extreme weather. Severe weather warnings for icy roads are a simple means of predicting fracture epidemics in advance, enabling timely public health and medical service provision response.

**Conflicts of interest statement**

None.

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