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Cold weather and GP consultations for respiratory conditions by elderly people in 16 locations in the UK

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Abstract. *Background*: Cold weather is associated with increases in mortality and demands on hospital services in the UK, particularly by the elderly. Less is known about the relationship with patterns of consultation in primary care. We wished to determine the magnitude and consistency of associations between cold temperature and consultations for respiratory conditions in primary care settings at different sites in the UK. *Methods*: Time series analysis of any short-term effects of temperature on daily general practitioner (GP) consultations made by elderly people (65+ years) for lower and upper respiratory tract infections (LRTI, URTI) over a 10-year period, 1992–2001. Practices were situated in 16 urban locations across the UK where a Met Office monitoring station was in operation. *Results*: An association between low temperatures and an increase in LRTI consultations was observed in all 16 locations studied. The biggest increase was estimated for the Norwich practices for which a 19.0% increase in LRTI consultations (95% CI 13.6, 24.7) was associated with every 1 °C drop in mean temperature below 5 °C observed 0–20 days before the day of consultation. Slightly weaker relationships were observed in the case of URTI consultations. A north/south gradient, with larger temperature effects in the north, was in evidence for both LRTI and URTI consultations. *Conclusions*: An effect that was consistent and generally strongest in populations in the north was observed between cold temperature and respiratory consultations. Better understanding of the mechanisms by which cold weather is associated with increases in consultations for respiratory infections could lead to improved strategies for prevention and reduced burdens for health services.

Key words: Cold weather, Primary care, Time series

Introduction

Ever since the 19th century a detrimental effect of cold weather on health has been observed in the UK [1]. The particular role of low temperatures was demonstrated using a variety of different health endpoints throughout the early part of the 20th century [2–7]. More recent studies have concentrated on the effects on mortality [8–10], particularly since the excess winter mortality rate in England and Wales has been observed to be much higher than those in other European countries with similar or lower mean winter temperatures [11].

The effects of this 'cold burden' on our health services are seen in the annual winter crises, with increasing demands placed on hospitals and lengthened waiting lists [12]. Many patient contacts occur at the primary care level, and as a result, the cold burden at this level of the health system could be considerable. A time-series investigation of short-term effects of low temperatures on general practitioner (GP) consultations made by people aged 65 and over in London found an increase in consultations for respiratory disease (but not cardiovascular disease) once daily mean temperatures dropped below 5 °C [13]. The strongest effects were observed with temperature values measured 2–3 weeks before the day of consultation.

Temperatures vary within the UK, with generally colder winters being experienced at more northerly latitudes. We conducted a time-series analysis of the relationship between cold weather and GP consultations for respiratory disease from practices based in 16 different locations throughout the UK to determine consistency of any cold effect on GP consultations and to investigate whether the magnitude of any relationship differed according to latitude.

Methods

Data on meteorological variables

Daily maximum and minimum temperatures and the 6am and 3pm relative humidity over a 10-year period (January 1992–December 2001) were obtained for various UK locations from the UK weather service, the Met Office. Daily average temperature and relative humidity measures were computed as the mean of their two respective values.

GP consultation data

Respiratory diseases are a major cause of primary care consultations in England and Wales [14]; therefore, daily counts of GP consultations made by those aged 65 years or more (elderly) for respiratory disease between January 1992 and December 2001 were obtained from the General Practice Research Database (GPRD). Lower respiratory tract conditions including asthma (ICD10 codes J11-J22, J40-J47, J60-J98) were analysed as this grouping made the largest contribution to consultations for respiratory disease. Separate analyses were also conducted for upper respiratory tract infections (J0-J6, J30-J39). Practices were selected if their postcodes shared the same first two digits as the postcode of the Met Office weather stations. In order to ensure anonymity of individual practices and to attain reasonable sample size, only clusters where at least three member practices were contributing data to each area were used in the final analyses. This resulted in 16 useable locations.

Air pollution and influenza data

Daily 24-hour average values of PM_{10} (particulate matter of less than 10 μm diameter) or black smoke (if PM_{10} was not available) were obtained from the UK National Air Quality Information Archive using pollution monitoring sites near each of the 16 weather station locations.

To control for the possible confounding effects of influenza, daily counts of consultations for influenza and influenza-like illnesses were also obtained from the GPRD for the same practices.

Statistical methods

Time series methods were used to investigate any association between temperature and GP consultations. These techniques control for any factors varying slowly over time such as changes in the number of registered patients, and so allow assessment of short-term effects (i.e. up to a few weeks duration) of temperature on disease. Generalised linear models were constructed for each series, using B-splines of time with equally spaced knots to control for secular trends and any additional confounding by seasonally varying factors other than temperature. Seven degrees of freedom (df) per year for these smoothing splines (roughly equivalent to a two-month moving average) were used. This number of degrees of freedom was chosen as a compromise between providing adequate control for unmeasured confounders and leaving sufficient information from which to estimate temperature effects. Indicator variables were used to allow for day-of-week and holiday effects, including any disruption during the Christmas and New Year period. Daily levels of influenza consultations and air pollution were incorporated into each model, and the possible confounding effects of humidity were controlled for using a natural cubic spline as graphical inspection suggested a weak non-linear relationship with consultation numbers. No significant interactions between mean temperature and humidity or with day-of-the-week were observed with respect to the health outcomes. The same confounder control (including the same amount of seasonal control) was conducted on each series to ensure uniformity across the locations.

Once all potential confounders had been included in the models, the relationship of consultation numbers with temperature was assessed. This was achieved by adding to each model a natural cubic spline of temperature (using 1 df for every 5 °C of the temperature range [15]). These allow the temperature-outcome relationship to be summarised and allow visual identification of a possible threshold value. Because the effect of cold weather on disease is known to be delayed [13], in the first instance the temperature measure used was averaged over the proceeding 3 weeks prior to consultation (lag 0–20 days).

For most locations, a clear linear relationship between temperature and consultations was observed once temperature values dropped below a threshold level of around 5 °C. For this reason, the cold effect was quantified by replacing the spline terms of temperature with a linear one for temperature values below the identified threshold. Poisson regression, allowing for overdispersion and autocorrelation if necessary, was then used to estimate the change in risk of consulting associated with every 1 °C change in temperature. All analyses were conducted in Stata 7.0 [16].

Results

Figure 1 shows the locations of the 16 clusters used. Table 1 shows the areas represented by each of these clusters and the number of practices contributing to the data. Table 2 shows the total number of consultations made by the elderly for lower and upper respiratory tract infections (LRTI/URTI) over the 10-year study period in each location. Also shown is the mean and the 10th and 90th percentile statistics for daily LRTI and URTI consultations by the elderly in each location, and the same summary statistics for temperature and relative humidity by location. As would be expected, in general the average value of temperature for this data-set increases from northern to southern locations.

Figure 2 shows the total weekly number of LRTI consultations by the elderly and the weekly average measure of mean temperature averaged across the

Figure 1. Study areas.

Table 1. Location and number of contributing practices

Met Office Weather Station	Latitude	Areas represented	No. of GPRD practices
Edinburgh airport	55.95°N	Edinburgh west, lower lying parts of city generally	3
Newcastle weather centre	54.98°N	City of Newcastle	4
Carlisle	54.93°N	Carlisle	4
Belfast, Aldergrove (airport)	54.65°N	Belfast	9
Leeds weather centre	53.80°N	City of Leeds	3
Manchester airport	53.36°N	South and south west Manchester	12
Norwich weather centre	52.63°N	City of Norwich	7
Birmingham airport*	52.29°N	Elmdon	8
Bedford	52.23°N	Bedford	3
Northolt	51.55°N	Northolt, Harrow, Pinner, Wealdstone	4
Heathrow	51.48°N	Staines, Feltham, Hounslow, Ashford, West Drayton	3
Bracknell (Beaufort Park)	51.39°N	Bracknell, Wokingham, Crowthorne	4
Farnborough	51.28°N	Farnborough, Aldershot, Frimley	3
Southampton weather centre	50.90°N	City of Southampton	3
Bournemouth/Hurn	50.78°N	Bournemouth, Poole, Christchurch	3
Plymouth (Mount Batten)	50.35°N	Plymouth	3

* Elmdon data to 31/03/1999, then Coleshill.

10-year period. A clear increase in LRTI consultations during the winter weeks is in evidence. The example shown is only for the practices contributing data for the Manchester area, although similar seasonal patterns were observed in all locations, and also for the URTI groupings.

Table 2. Summary statistics of respiratory consultations and weather variables

Location	Total no. of LRTI consultations by elderly	Total no. of URTI consultations by elderly	LRTI consultations by elderly	URTI consultations by elderly	Mean temperature	Relative humidity
			Daily mean (10th, 90th percentile)			
Edinburgh	5544	2057	1.5 (0, 4)	0.6 (0, 2)	9.0 (2.8, 15.4)	80.0 (69.7, 90.5)
Newcastle	12381	5027	3.4 (0, 8)	1.4 (0, 3)	9.8 (3.6, 16.2)	75.5 (63.7, 88.3)
Carlisle	22113	7317	6.1 (0, 13)	2.0 (0, 5)	9.4 (3.1, 15.6)	80.8 (70.0, 90.7)
Belfast	31205	9477	8.5 (0, 18)	2.6 (0, 6)	9.4 (3.5, 15.4)	82.5 (72.1, 91.5)
Leeds	4719	1611	1.3 (0, 3)	0.4 (0, 2)	10.4 (3.6, 17.2)	76.1 (63.7, 89.3)
Manchester	23148	10006	6.3 (0, 13)	2.7 (0, 7)	10.1 (3.5, 16.7)	78.1 (65.6, 89.4)
Norwich	28019	11103	7.7 (1, 15)	3.0 (0, 7)	10.7 (3.9, 17.8)	77.9 (65.1, 90.3)
Birmingham	28652	13264	7.8 (1, 16)	3.6 (0, 8)	9.9 (3.0, 16.9)	80.5 (66.7, 93.1)
Bedford	8146	2624	2.2 (0, 6)	0.7 (0, 2)	9.9 (2.9, 17.1)	78.9 (65.2, 91.9)
Northolt	13125	5228	3.6 (0, 8)	1.4 (0, 4)	11.1 (3.7, 18.5)	75.9 (61.6, 89.2)
Heathrow	2773	992	0.8 (0, 2)	0.3 (0, 1)	11.5 (4.3, 18.9)	76.0 (62.2, 88.7)
Bracknell	15125	5336	4.1 (0, 9)	1.5 (0, 4)	10.4 (3.2, 17.5)	79.3 (66.3, 91.4)
Farnborough	9902	4698	2.7 (0, 6)	1.3 (0, 3)	10.5 (3.1, 17.7)	80.2 (67.2, 91.8)
Southampton	12361	3773	3.4 (0, 8)	1.0 (0, 3)	11.7 (5.0, 18.6)	75.8 (61.2, 89.3)
Bournemouth	17305	8319	4.7 (0, 11)	2.3 (0, 5)	10.5 (3.5, 17.4)	82.3 (70.9, 92.7)
Plymouth	3962	823	1.1 (0, 3)	0.2 (0, 1)	11.0 (5.4, 16.8)	83.7 (70.9, 95.0)

Figure 3 shows the relationship between the relative risk of an LRTI consultation in the elderly age-group and mean temperature (averaged across the previous 3 weeks), by location. The centre line in each graph is the estimated spline curve, and the upper and lower lines represent the 95% confidence limits. The relationship is seen to be similar in all locations, and is only difficult to interpret in locations with few consultations such as Leeds and Plymouth where the confidence intervals are wide. In general, a low risk of consulting is seen at the top end of the temperature range; this could reflect the time of summer holidays when many patients and practitioners are away. At the lower end of the temperature range, a strong increase in relative risk is observed, particularly once temperatures drop below a certain value. Comparison of model diagnostics suggested this value was 5°C in most locations. The relationship below this point is broadly linear.

Figure 4 shows the percentage excess risk (95% CI) estimated for a linear association between LRTI consultations by elderly people in the Manchester practices and temperature values below 5 °C. The percentage excess risk in consultations is derived from the relative risk (RR) by the following formula: (RR−1)*100. The *y*-axis represents the change in LRTI consultations associated with every 1 °C decrease in temperatures below values of 5 °C; and the *x*-axis shows the sum of the effect at successively cumulative lags of the temperature measure. The estimate is based on models with separate terms for each individual lag measure, so, for example, lag 0 estimates the risk associated with cold temperatures on just the same day as the day of consultation, and the effect at lag 1 represents the contribution from the day before as well as the same day, etc. It is clear from the graph that little effect is observed until measures are lagged by 2–3 weeks, and then levels off at lag 20, after which no additional cold effect is observed. Because the effect size is not uniformly spread across the different lag measures, all subsequent results are based on models with individual lag terms summed together (unconstrained distributed lag model) rather than on an average measure. Similar distributions were observed in other locations, and for the URTI groupings.

Figure 5a shows the quantification of the cold effect by location (Plymouth is not shown due to very wide confidence intervals). For each location, the percentage excess risk (95% CI) in LRTI consultations is that associated with temperature values below 5 °C summed across individual lag measures 0–20 days before the day of consultation. A positive association was observed in all locations studied. Effects were slightly smaller in the URTI grouping (results not shown).

The cities in Figure 5a have been ordered by latitude (north – south). The effect is generally seen to increase with increasing latitude, with this trend being statistically significant at the 5% level. This was the case for URTI results also (not shown). Figure 5a, however, does not take into account the fact that northern cities will also experience more days below 5 °C. Figure 5b shows the attributable fraction for the LRTI group for each location, again ordered by latitude. The attributable fraction estimates the percentage of consultations attributable to temperatures below 5 °C and, as a result, the north/south gradient becomes more pronounced.

Figure 3 showed the relationships between the risk of an LRTI consultation and mean temperature. With most locations, the risk of consulting seemed

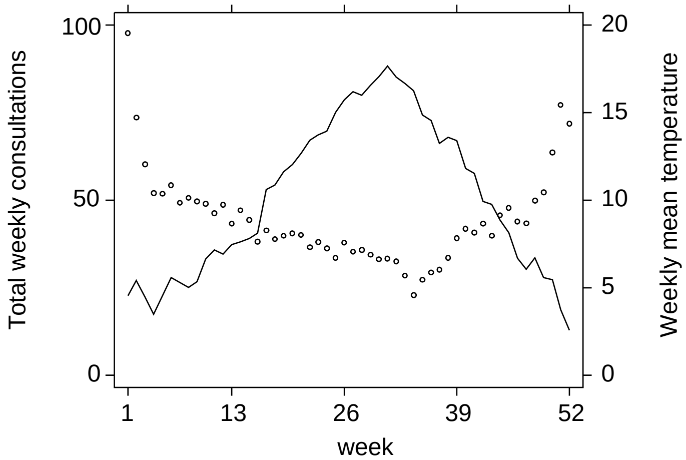

Figure 2. Seasonal distribution of total weekly LRTI consultations (circles) and weekly mean temperature (line) in Manchester study area.

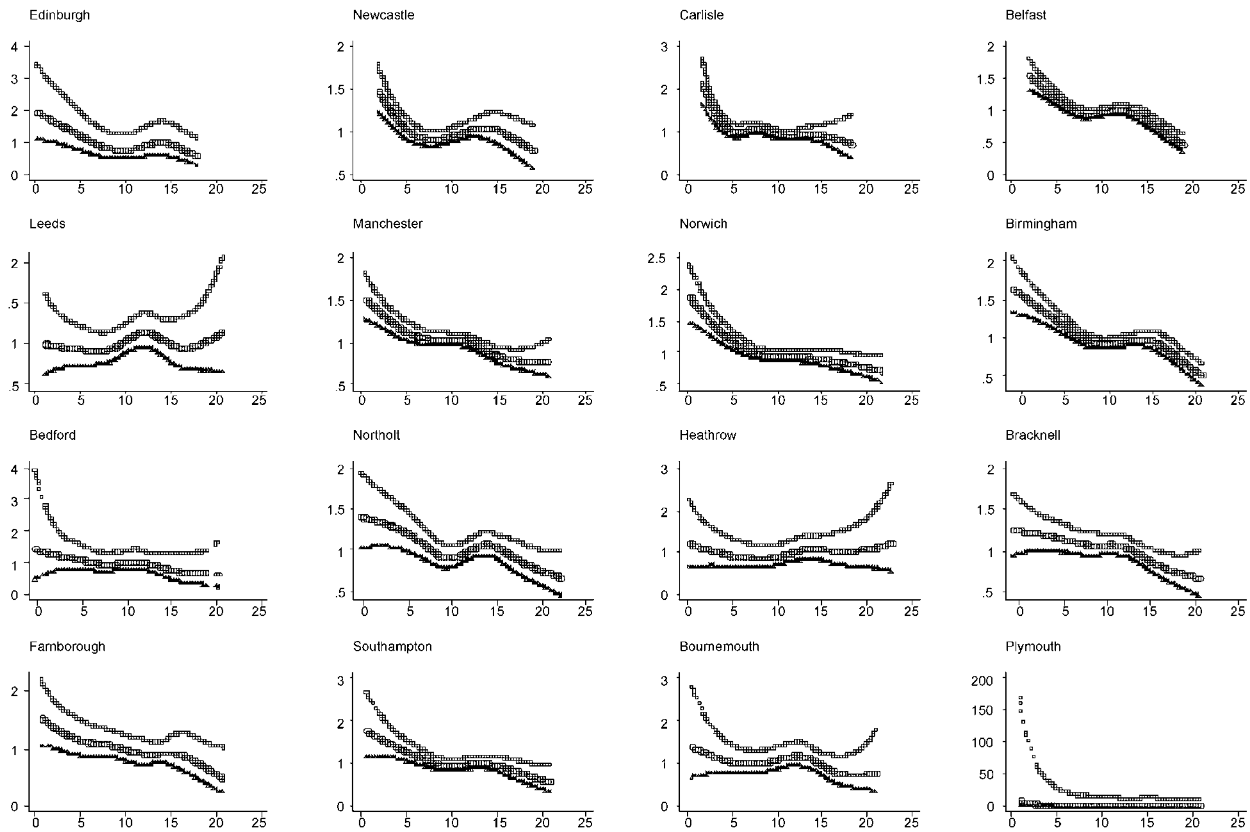

Figure 3. Relationship of LRTI consultations in elderly people with mean temperature (average of lags 0–20), by location. For each graph, the x-axis provides the range of the temperature measure, and the y-axis represents the relative risk of consulting after adjustment for other factors. The centre line in each graph is the estimated spline curve, and the upper and lower lines represent the 95% confidence limits.

lowest at the top end of the temperature range, probably because these days fall around the month of August when many people are likely to take their holidays, resulting in a drop in consultation numbers. Were this the case then increasing the amount of seasonal control would pick up this 'summer holiday effect'. Figure 6 shows the temperature/consultation relationship in the Manchester practices, first after the set amount of seasonal control conducted in all locations, and secondly when the amount of seasonal control is doubled, resulting in more of the seasonal patterns being controlled for. One can see that the cold effect remains similar to before (albeit with slightly wider confidence limits), but a possible increased risk of consulting associated with values at the higher end of the temperature range also now

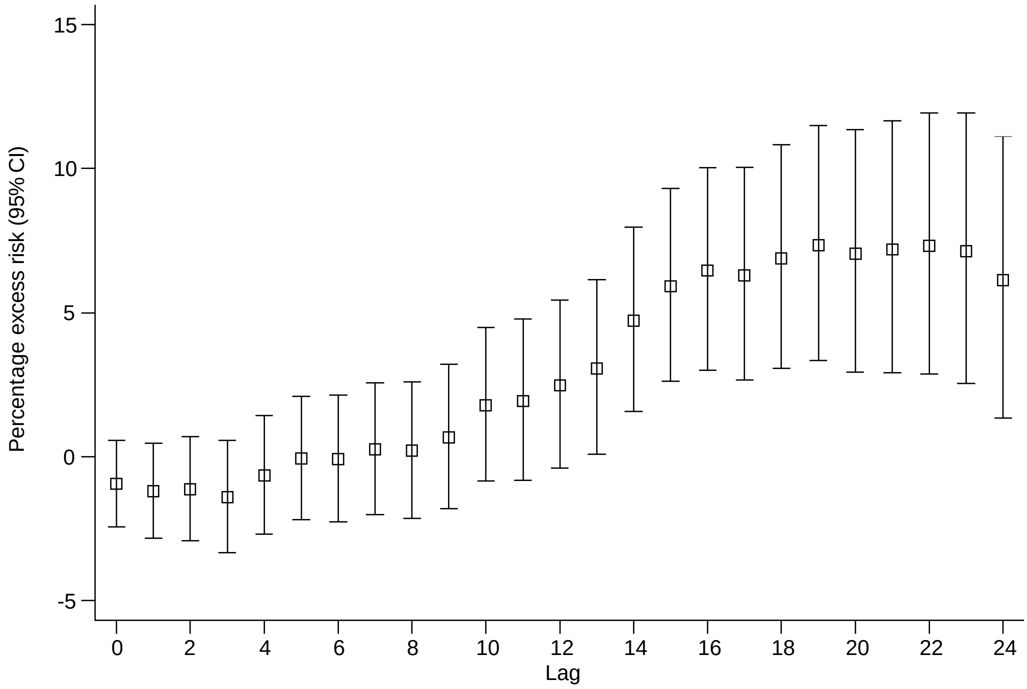

Figure 4. Percentage excess risk (95% CI) in number of LRTI consultations associated with every 1 °C decrease in mean temperature below 5 °C, by summed lags of temperature. Results shown for Manchester practices.

develops. This linear 'heat effect' is, however, very imprecisely estimated.

The original amount of seasonal control involved using cubic splines with 7 df for every year of data. When the degree of seasonal control is increased above this amount, adding 1 df at a time, up to splines with 14 df per year, the resultant cold estimate remains steady (with slight loss of precision) as the seasonal control is increased (conducted on Manchester practices, not shown). With the heat estimate, however, the effect is very dependent on the degree of control used, with the negative estimate observed using 7 df becoming progressively positive as more dfs are employed. In models using 14 df per year, a potentially large positive effect becomes apparent though is very imprecisely measured: 8.9% (95% CI: 10.2–32.1) increase in consultations for every 1 °C increase in temperature measures above 18 °C (again chosen by model diagnostics) summed for individual lags 0–20. Similar analyses on the other locations with large consultation numbers again suggested either a cold estimate very robust to seasonal smoothing (Carlisle and Norwich) or one that changed slightly but not significantly so (Belfast and Birmingham); but in each case an apparent heat effect became evident in models with greater seasonal control (not shown).

Discussion

An association between cold weather and respiratory consultations was observed in this elderly group. The elderly are likely to be most affected due to age-related impairment of respiratory function [17]. An elevated risk was present in all 16 locations studied, with the biggest increase estimated for the Norwich practices: a 19.0% (95% CI: 13.6–24.7) increase in lower respiratory consultations was associated with every 1 °C drop in mean temperature below 5 °C summed for 0–20 days prior to consultation. The long lag times observed between the exposure and the outcome may, to some extent, be explained by the time taken to arrange an appointment to see a GP, but the delayed effect is likely to be partly due to the underlying pathological mechanisms involved, as similar lag times are observed with mortality [18]. Increases in respiratory disease may be attributed to cross-infection from indoor crowding, adverse effects of the cold on the immune system, and to the fact that low temperatures assist survival of micro-organisms in droplets [19]. In addition, recent evidence suggests a role for direct cooling of the respiratory tract [20], and cold air breathing may also induce bronchospasm by causing inflammatory changes in the airway [21].

A clear north/south gradient, with larger temperature effects in the north, was in evidence in our data. An investigation by Fleming [22] into geographical variations in GP consultation rates in England and Wales found a slightly higher prevalence of respiratory disease in the north. Curwen observed little regional variation in an excess winter death index, although a slight north/south gradient was in evidence [11]. A report by Wilkinson et al. also reported a weak north/south gradient, which they comment is

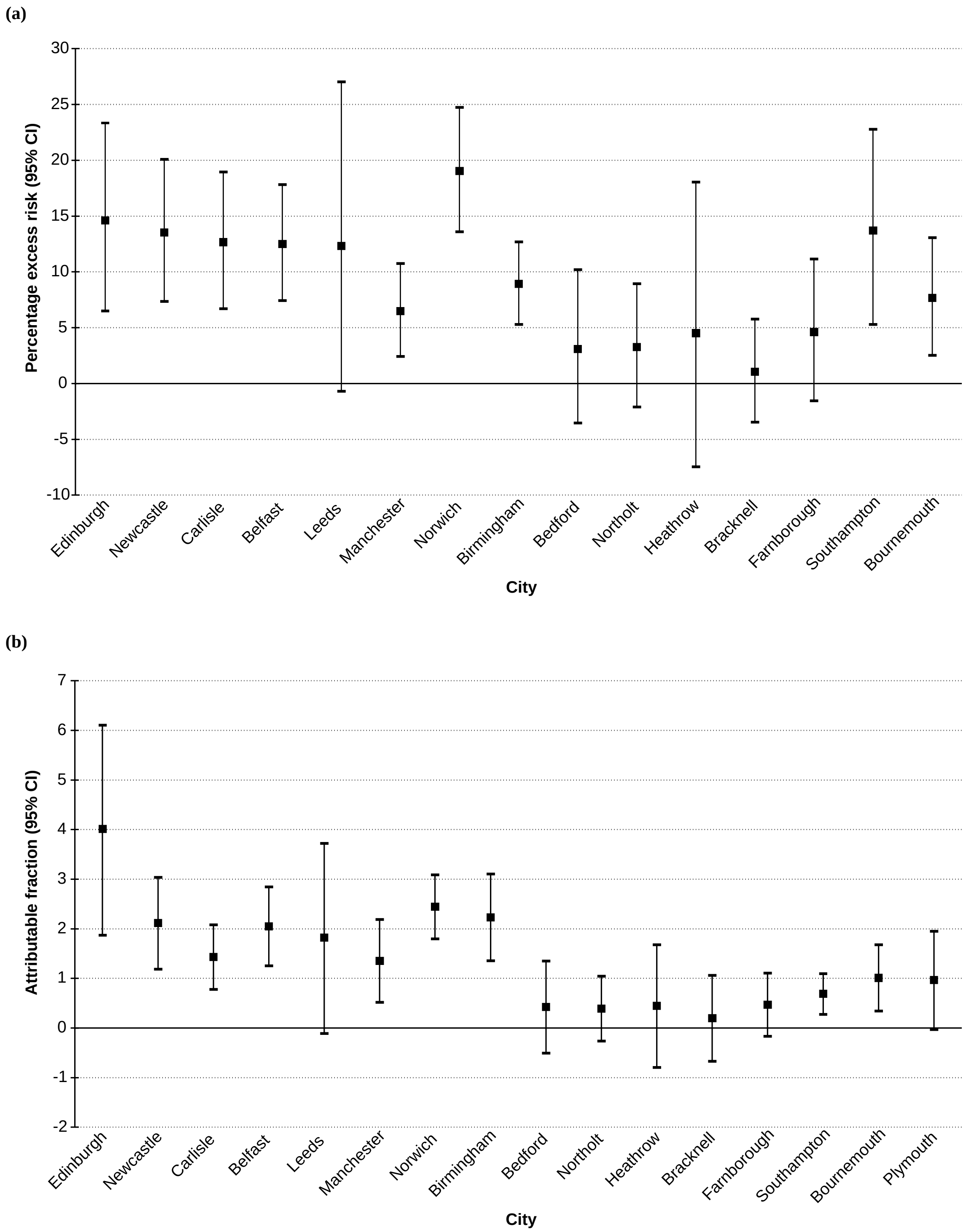

Figure 5a. Percentage excess risk (95% CI) in number of LRTI consultations associated with every 1 °C decrease in mean temperature below 5 °C, by location and in order of decreasing latitude. **5b**: Percentage of LRTI consultations attributable to mean temperatures below 5 °C, by location and in order of decreasing latitude.

compatible with a climate effect, although such a pattern might also be seen with other explanations [23]. In our study, the population structure within the elderly age-grouping could differ by location and therefore could contribute to the north/south gradient. The UK 2001 Census data, however, shows that the proportion of people aged 80 or over compared to all those aged 65 is lower in the north than in the south: 23.6% in the North East region compared to 28.1% in both the South East and South West. This does not, however, exclude the possibility that the health of elderly people may be better in the south. Confounding by social class could also be an explanation of the gradient since studies have shown that excess winter mortality can be higher among lower social classes [24], although other studies have

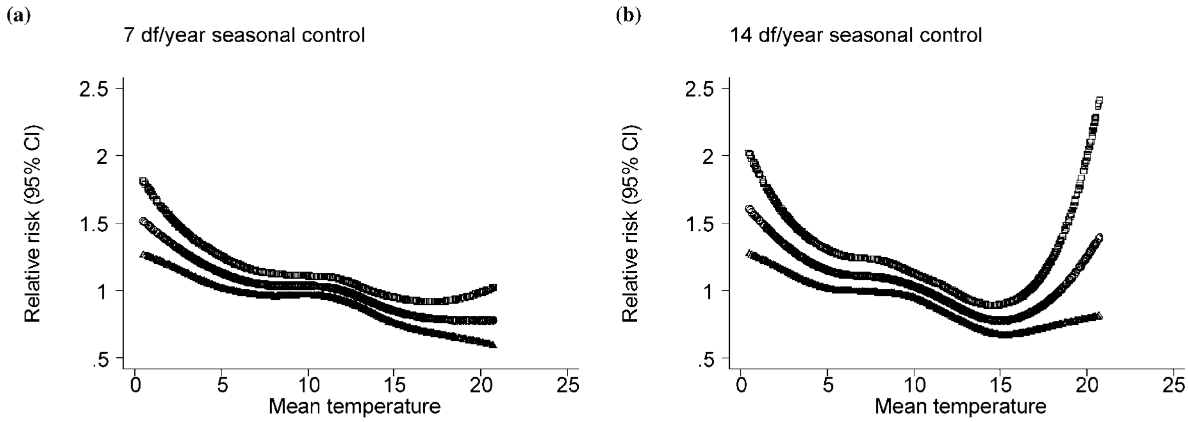

Figure 6. Relationship of LRTI consultations in elderly people with mean temperature (average of lags 0–20) in the Manchester practices; a) using 7 df per year to control for slow time-varying factors, and b) using 14 df per year.

observed no association with deprivation in the UK [25, 26]. Although a study by Lawlor et al. [27] found no association between rurality and excess winter mortality, it has been suggested that people in rural areas of Britain have increased exposure to low temperatures both indoors and outside. The regional differences observed in our study could not be explained by rurality as all locations are urban. The temperature signal may have been diluted to some extent by the fact that matched participating GP practices were only required to share the same first two digits of the weather station postcodes. The degree of dilution is likely to vary by location, however there is no reason to suspect that this may have happened in a systematic fashion by latitude. The north/south trend was less pronounced once cities were ranked in order of increasing mean winter temperature. This could suggest that some other factor (that is latitude-related) could explain the gradient. An association of rainfall with inter-town mortality due to heart disease in England and Wales has been demonstrated [28]. In our study relative humidity and its possible interaction with temperature was adjusted for in all regression models. Other weather variables such as wind-chill could perhaps explain the large increase observed in the case of Norwich and requires further investigation. Similarly, other potential explanations for the inter-town variability exist, e.g. housing type, that could be explored as part of a hierarchical modelling strategy, however detailed information on each of these factors would first be required.

In general, the attributable fractions calculated in this study were small. For example, in Edinburgh an estimated 4.0% (95% CI: 1.9–6.1) of all lower respiratory consultations by the elderly group could be attributed to days when mean temperatures were below 5 °C. These attributable risks, however, do not take into account temperature values across the whole range, but only at the extreme lower end where the relationship is strongest. With mortality, the range of temperatures at which no health effect is observed (from either heat or cold) is relatively small [29]. In the case of GP consultations, it seemed that this band was much wider, with a cold effect not being fully observed until mean temperatures dropped below 5 °C. It is perhaps at these relatively low values of temperature where a weather forecasting system could potentially be most useful in anticipating rises in consultations for respiratory problems.

Our database records elective as well as emergency consultations, so patients presenting with acute problems could not be separated from those coming in for routine review. As a result, any weather signal is likely to be dampened, and estimates are likely to be underestimates. Any study looking at the association between respiratory conditions and temperature needs to make careful allowance for potential confounding effects of influenza epidemics. The daily number of consultations for influenza and influenza-like illness in out study practices was included in all models regardless of statistical significance. A check of the model diagnostics suggested this provided adequate control for the potential confounding effects of influenza.

Recent discussions in the scientific community of the most appropriate methods to employ for seasonal control have also raised the issue of how much control for seasonality is appropriate [30]. Our investigations suggested that when seasonal control was increased, no bias was introduced into our cold effect estimate, although imprecision was increased. However, the presence of a possible association with heat, the effects of which are considered to be much more immediate (i.e. shorter lags), was very dependent on the degree of seasonal control. The possible U-shaped relationship between consultations and the whole range of temperature that developed with larger amounts of seasonal control (Figure 6b) is similar to what is observed between temperature and mortality [31]. The possibility of respiratory consultations being affected by hot temperatures needs further investigation, but the burden of a potential heat effect, although small in comparison to cold weather, could become increasingly onerous due to potential changes arising from global warming if acclimatisation does not occur.

Keatinge and Donaldson [32] have stressed the need for government policy to be focussed on tackling outdoor cold exposure. This study does not permit us to determine whether outdoor or indoor exposure to cold is more important in influencing respiratory infections, however a better understanding of mechanisms of associations is clearly needed in order to determine how best to prevent diseases sensitive to meteorological conditions.

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