Associations of cold temperatures with GP consultations for respiratory and cardiovascular disease amongst the elderly in London

S Hajat and A Haines

Background  The relationships between cold temperatures and cardio-respiratory mortality in the elderly are well documented. We wished to determine whether similar relationships exist with consultations in the primary care setting and to assess the lag time at which the effects were observed.

Methods  Generalized additive models were used to regress time-series of daily numbers of general practitioner (GP) consultations by the elderly against temperature, after control for possible confounders and adjustment for overdispersion and serial correlation. Consultation data were available from between 38,452 and 42,772 registered patients aged ≥65 years from 45–47 London practices contributing to the General Practice Research Database between January 1992 and September 1995.

Results  There was little relationship between consultations for respiratory disease and mean temperature on the same day as the day of consultation. However, a strong association was apparent with temperature levels up to 15 days previously, with an increase in consultations being observed particularly as temperatures drop below 5°C. Every 1°C decrease in mean temperatures below 5°C was associated with a 10.5% (95% CI: 7.6%, 13.4%) increase in all respiratory consultations. No relationship was observed between cold temperatures and GP consultations for cardiovascular disease.

Conclusions  Our study suggests a delayed effect of a drop in temperature on consultations for respiratory disease in the primary care setting. Information such as this could be used to help prepare practices to anticipate increases in respiratory consultation rates associated with low temperatures.

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A known relationship exists between temperature and mortality.1–5 In general increased death rates occur principally in the elderly6 and the relationship is considered to take the form of a ‘V’ or a ‘U’ shape, with the lowest death rates occurring on days of moderate temperature and highest rates at either end of the temperature range.7,8 In the UK a 2% increase in mortality has been estimated for every one degree fall in temperature from 18°C.9 Most of the excess mortality is due to respiratory, cardiac and cerebrovascular disease. Furthermore, the effect on these diseases of cold temperatures has been reported to occur over prolonged periods, in some cases up to a few weeks duration.10,11

A study of the relationships between registered deaths in the elderly and weekly data for the incidence of respiratory disease presenting to general practitioners (GPs) found a strong positive association between the two health outcomes.12 Despite this, one study could not establish any relationship between environmental factors and accounts of asthma or exacerbation of chronic bronchitis on the Swiss sentinel reporting system.13 However, more recent work from the UK has shown that a drop in temperature is associated with a rise in bronchitis consultation rates some 10–17 days later.14

In order to establish whether or not cold temperatures are associated with consultations in the primary care setting and to assess the lag time at which effects are observed, we carried out a time-series analysis of daily GP consultations with elderly
patients in London between January 1992 and September 1995. Our study seems unique in that no previous long-term time-series analysis appears to have been undertaken to investigate the association of consultations with ambient temperature in the primary care setting.

Methods

GP consultation data
Daily counts of GP consultations for various respiratory and cardiovascular complaints between January 1992 and September 1995 were obtained from the GPRD (General Practice Research database). The data have been used to assess associations between air pollution and consultations for respiratory conditions. The data consist of anonymized computerized patients’ records and are currently available from the Medicines Control Agency who manage the GPRD on behalf of the Department of Health. Participating practices are required to record all significant morbidity with dates, all drugs prescribed with dates, an indication (diagnosis) for each acute prescription, and the initial indication for any repeat prescription. The database records daily numbers of people consulting rather than the number of consultations made, so a person seeking two or more consultations on the same day would only be recorded once on the database; however, for brevity, we adopt the term ‘number of consultations’ in this paper.

An a priori decision was made to study the elderly (≥65-year-old) in the first instance as this is the most vulnerable age group to effects of temperature on health. For the period analysed, 38 452–42 772 registered patients aged ≥65 from between 45 and 47 practices in the Greater London area were contributing to the database. Information on the daily number of consultations from this group were obtained for the following respiratory or cardiovascular complaints: asthma (International Classification of Diseases, Ninth Revision [ICD-9] code 493); lower respiratory disease (LRD) excluding asthma (ICD-9 codes 464, 466, 476, 480–483, 485–492, 494–496, 500, 501, 503–505, 510–555, 518, 519, 786); upper respiratory disease (URD) excluding allergic rhinitis (ICD-9 codes 460–463, 465, 470–475, 478); and cardiovascular disease (CVD) (ICD-9 codes 390–403, 410–416, 420–429, 785).

Data on meteorological variables and potential confounding factors
Daily maximum and minimum temperatures and the 6 a.m. and 3 p.m. relative humidity at Holborn in central London were obtained from the Meteorological Office. Daily average temperature and relative humidity measures were computed as the mean of their two respective values.

Air pollution measures were obtained from monitoring stations distributed throughout London. Sulphur dioxide (SO₂) data were obtained from five sites dispersed across London, ozone (O₃) from two sites, and one central site provided data on particulate matter of <10 μm in diameter (PM₁₀). Daily 24-hour average values were monitored in the case of SO₂ and PM₁₀ and the daily maximum 8-hour moving average measure for O₃. A series consisting of the arithmetic mean of daily values of all monitoring stations was constructed to obtain a single daily average value for London for each pollutant.

Pollen data from the London site of the National Pollen Network were obtained from the National Pollen Research Unit at Worcester. Data on the daily maximum 2-hour and 24-hour average concentrations of pollen grains per cubic metre were available. The pollen types considered were hazel, birch, alder, oak, nettle, grasses, plantain, lime, dock, chestnut and willow.

Statistical methods
The analytical approach followed standard time-series methods that have been developed for air pollution studies. These involved the use of generalized additive models (GAM) with non-parametric smoothers to control for seasonal patterns. The approach takes into account any variations in the denominator over time, and so allows for a seasonally-adjusted baseline against which the measurement of the effects of temperature can be made. A loess smoother was used in this study as, relative to other smoothers, it has a particular local behaviour and so should pick up awkward shapes in the data well. The span of the smoother was varied to control the amount of smoothing carried out on the time-series data. The aim was to select a span that removed mid- to long-term seasonal cycles but which left patterns of a short-term nature since it is these that may be due to fluctuations in temperature. In order to determine the correct amount of smoothing needed a relatively large span was initially used and the model diagnostics examined. Successive reductions in the smoothing window were then made, with a reassessment of model diagnostics at each step. Goodness of fit of each statistical model was assessed from the model residuals, the dispersion-penalized AIC (Akaike’s Information Criterion), and the partial auto-correlation function (PACF) to determine the degree of remaining serial-correlation (non-independence of adjacent days).

Indicator variables were used to allow for day-of-week, Christmas, New Year, Easter and bank holidays, and thunderstorm effects. The daily number of consultations for influenza (also obtained from the GPRD) were incorporated into each model as a possible confounding variable. Based on previous work, each air pollutant measure was averaged across lags 0 and the previous 2 days lags; then each of these terms, as well as lagged daily pollen levels, were added to the model if statistically significant at the 1% level. The possible confounding effects of humidity were controlled for using a broad smoothing spline (6 degrees of freedom [d.f.]) 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 our health outcomes.

Once all potential confounders had been included in the model, the relationship of consultation numbers with temperature was assessed. This was achieved by adding to the model a smoothing spline for temperature (again using 6 d.f.) and then plotting the smoothed effect. This was conducted for temperature on a lag of 0 (day of consultation) to assess any immediate effects, and then repeated for longer day lags to explore a more prolonged effect. Poisson GAM regression, allowing for overdispersion and autocorrelation if necessary, was used to estimate the percentage change in consultations associated with a 1°C change in temperature. This was conducted initially for temperature on single days and then again for the combination of a number of days as the effects of temperature are likely to occur over...
periods of time rather than from the contribution of one day alone. The percentage change in consultations is derived from the relative risk (RR) by the following formula: \((RR-1) \times 100\). All analyses were carried out using the statistical package S-plus.19

**Results**

Table 1 shows, by season, the mean, standard deviation, and 25th and 75th centiles of the meteorological variables and the daily number of consultations by diagnoses. As would be expected, mean consultation numbers were higher in the cool season compared to the warm, especially for respiratory diseases. Figure 1 shows the time-series of the daily number of all cardio-respiratory consultations made by people aged \(\geq 65\) in the study period. This clearly shows a yearly pattern in consultation numbers, with the peaks occurring during the winter months. The separate band of low consultation numbers along the bottom of the plot reflects the few consultations made during Saturdays and Sundays when most practices are closed. This strong day-of-week effect was adjusted for as part of the statistical modelling. The line indicates the amount of smoothing carried out to control for seasonality.

Figure 2 shows the relationship of all respiratory disease consultations (asthma, other LRD and URD combined) with temperature on various different lags after adjustment for potential confounders. The x-axis on each graph is the range of mean temperature. The y-axis on each graph represents the consultation rate as a percentage of the average number of consultations, so a day on which the consultation rate is above 100 suggests an above average number of consultations, and a day below 100 suggests consultation numbers were less than average. The first graph shows the relationship of consultations with temperature measures on the same day as the day of consultation (lag 0). The next graph shows the relationship with temperature measures 3 days before consultation (lag 3), the next with 6 days before, and so on up to 24 days before the day of consultation. It should be noted that there will be some degree of correlation between these different legs of the temperature measure. The first graph indicates that consultation numbers are at their highest when same-day temperatures are at moderate levels, and that consultation numbers broadly seem to decrease as the temperature goes either up or down. However, the majority of the relationship is flat and so seems mainly unrelated to same-day temperature. The low number of consultations at the top end of the temperature range is consistent across all lags (subsequent graphs) and probably reflects the time of summer holidays. At the lower end of the temperature range, a clear relationship with consultations develops as the temperature measure is lagged. A strong increase in consultations is observed, particularly as the temperature drops below about 5°C; this relationship is linear and is observed at about a lag of...
of 6 days onwards, and continues for about 10 days up until measures on a 15-day lag. This suggests that cold temperatures may not have an immediate effect on consultations for respiratory disease, but may have a strong influence on rates up to 2 weeks later. Beyond this time, the relationship becomes progressively weakened. A very similar pattern was observed when looking separately at either asthma, other LRD or URD.

Figure 3 shows the relationships observed with CVD consultations. Again, the relationship with same-day cold temperatures is relatively flat, but, in contrast to the relationship with respiratory diseases, remains so with most other lags also. The decrease in consultation numbers at high temperatures again probably reflects the summer holiday period.

Table 2 shows, for various diagnoses, the percentage change in consultations associated with a 1°C drop in temperature below 5°C. Statistically significant associations were observed for various single days of the temperature measure, however, since the graphical analysis suggested a contribution over a period of a number of days, the temperature measure is represented by the average value across lags 6 to 15, with adjustment for other lags. The estimate provided for the LRD group may be slightly misleading as the relationship was significantly non-linear ($P = 0.01$). With every other diagnosis the relationship of consultation numbers was linearly related to the temperature measure. The table shows that every 1°C decrease in mean temperature below 5°C was associated with a 12.4% (95% CI: 0.7%, 25.4%) increase in asthma consultations. Due to the comparatively low number of consultations for asthma made by this age group, the confidence intervals are very wide. Cold temperatures were also associated with an increase in consultations for URD. However, as Figure 3 suggested, there was no significant association between cold temperatures and consultations for CVD. A 1°C decrease in mean temperature below 5°C was associated with a 10.5% (95% CI: 7.6%, 13.4%) increase in all respiratory consultations.

**Discussion**

We detected an association of cold temperature with respiratory consultations made by people aged ≥65 in London. The effect was strongest for asthma, although confidence intervals were wide due to the small number of consultations made by this age group. The upper respiratory grouping, which included conditions such as the common cold, acute sinusitis, acute pharyngitis and acute tonsillitis was also positively associated with cold temperatures. We estimated a 10.5% (95% CI: 7.6%, 13.4%) increase in all respiratory consultations associated with a 1°C drop in temperatures below 5°C. This was the effect of temperature measures averaged over a 10-day period from 6–15 days before the day of consultation. The mechanism of the observed association may be due to increased crowding and/or
reduced indoor ventilation in colder periods resulting in increased viral transmission. The absence of a clear relationship with consultations for CVD is to be expected and probably reflects the chronic nature of this diagnostic grouping, with many of the consultations being for review rather than acute symptoms. Acute events of CVD are more likely to take patients straight to hospital\textsuperscript{20,21} or to cause death\textsuperscript{11,22}.

As with mortality, the effect of cold temperatures was only seen when the temperature measure was lagged, in this case by up to 15 days and peaking at about 10–12 days previously, suggesting a delayed effect on respiratory conditions. Lag effects beyond about 30 days were not considered, as the methodology employed adjusts for mid- to long-term patterns and so estimates from longer day lags may be inaccurate due to the adjustments made in the statistical model for seasonality.

One very important aspect of the GPRD database used in this study is that it records both elective as well as emergency consultations but does not distinguish between the two. So it was impossible to separate those people coming in for an emergency consultation from those simply visiting their GP for a routine prescription. One very obvious case of this would be those people suffering from asthma who may be reviewed from time to time to check on adherence to medication and to monitor symptoms and respiratory function. Primary care data, more than any other health outcome, are likely to be influenced by patient behaviour and service availability. As a result, the time-series data obtained were very ‘noisy’ as so many factors could contribute to a patient’s final decision to consult a doctor. As a result, any true signal of environmental factors may have been diluted, so the effect sizes presented in this paper may be underestimates.

Due to reasons of confidentiality, at the time of the study it was impossible to obtain a breakdown by location of individual
practices. Instead, combined numbers for the whole of Greater London had to be used to detect associations with temperature; for this reason, one site in central London was used to represent temperature levels.

Mean temperature (defined as the average of daily maximum and minimum temperature) was used as the predictor variable in all models. As judged by comparison of model AICs (a measure of goodness of fit on the model), mean temperature was considered to be a better predictor of consultation numbers compared to either maximum or minimum temperature.

Any study looking at associations between cardio-respiratory conditions and temperature has to make careful allowance for potential confounding effects of influenza epidemics. The daily number of consultations for influenza in our study practices was included in all models regardless of statistical significance. A check of the model diagnostics suggested this approach provided adequate control for the potential confounding effects of influenza.

In conclusion, our study suggests a delayed effect of a drop in temperature on consultations for respiratory disease. Information such as this could be used to help prepare practices to anticipate increases in consultation rates associated with prolonged periods of low temperature.

**KEY MESSAGES**

- An association of cold temperatures was observed with GP consultations for respiratory disease but not with cardiovascular disease consultations.
- The association with respiratory disease consultations was observed with temperature levels up to 15 days previously, suggesting a delayed effect of cold temperatures.
- Information such as this could be used to help prepare practices to anticipate increases in respiratory consultation rates associated with cold temperatures.

**References**
