Can primary care data predict those most vulnerable to cold weather?

Abstract

Background:

NICE recommends GPs use routinely available data to identify patients most at risk of death and ill-health from living in cold homes.

Aim:

We investigated whether socio-demographic, medical and house quality characteristics could predict cold-related mortality.

Design and Setting:

A case-crossover analysis was conducted on 34,777 patients aged 65+ from the Clinical Practice Research Datalink who died between April 2012 and March 2014. From Meteorological Office data, we calculated average temperature of date of death and 3 days previously. We also calculated the average 3-day temperature for the 28th day before/after date of death, and compared those temperatures with those experienced around the date of death.

Method:

Conditional logistic regression was applied to estimate the odds ratio (OR) of death associated with temperature and interactions between temperature and socio-demographic, medical and house quality characteristics, expressed as relative odds ratios (RORs).

Results and Conclusion:

Lower 3-day temperature was associated with higher risk of death (OR 1.011 per 1^{o}C fall; 95%CI 1.007-1.015; p<0.001). No modifying effects were observed for socio-demographic, medical and house quality characteristics. Analysis of winter deaths for causes typically associated with excess winter mortality (N=7,710) showed some evidence of a weaker effect of lower 3-day temperature for women (ROR 0.980 per 1°C, 95%CI 0.959-1.002, p=0.082), and a stronger effect for patients living in northern England (ROR 1.040 per 1°C, 95%CI 1.013-1.066, p=0.002). It is unlikely GPs can identify older patients at highest risk of cold-related death using routinely available data, and NICE may need to refine its guidance.

How this fits in

Because of excess winter mortality in England and Wales, NICE recommends GPs use existing data to identify patients most at risk from living in a cold home.

When analysing routine data from over 300 general practices on patients aged over 65 who died over a two-year period, we found that every 1^{0}C drop in temperature was associated with a mortality increase of 1.1%.

However, we found little evidence that vulnerable subgroups could be identified using routine data.

It is unlikely that GPs can use medical records to identify older patients most at risk from cold weather.

Introduction

The phenomenon of excess winter deaths, whereby the death rate is higher during winter months than at other times of the year, is found worldwide, but appears particularly marked for the UK.(1-3) It is generally thought that there are two biological mechanisms, increased blood pressure and increased clotting, through which cold might exert its effect.(4) The twin environmental issues of cold housing and fuel poverty have been highlighted.(5) Wilkinson and associates found associations between excess winter mortality and the age of the property, and poor thermal efficiency ratings.(6) Though ecological studies in the UK found no relation of deprivation to increased mortality during cold weather, some evidence was found for age, gender, and medical (chronic) conditions.(7-11) In 2015, the National Institute for Health and Care Excellence (NICE) guideline on excess winter deaths(12) recommended that primary care team practitioners should help identify people at risk of ill health from living in a cold home in collaboration with relevant local authority departments, using existing data and professional contacts. Assessing the heating needs of primary care patients once a year should be done during a home visit or elsewhere.(13, 14) We aimed to assess whether primary care staff are able to identify people at risk during cold snaps, using a simple algorithm based on information on clinical factors, socio-demographic characteristics, living situation and location provided in electronic patient's records (EPR). As GP home visits are undertaken opportunistically rather than systematically, and cannot reliably identify all those at risk from poorly heated homes, we used house energy efficiency at LSOA level as a marker of risk. We focused on patients aged 65 and over as these patients are most at risk from temperature-related mortality.(8)

Methods

Study design and setting

We obtained data from the Clinical Practice Research Datalink (CPRD), which contains current data on 4.4 million anonymised patient records (6.9% of the UK population) and are nationally representative for age, sex and ethnicity.(15) The patients' postcode is recorded at the general practice, and used to assign a lower super output area (LSOA) of residence. The CPRD can be linked with Hospital Episode Statistics (HES) and Office for National Statistics (ONS) mortality data in England(16), and we investigated patients in CPRD who could be linked by their NHS number to these data in England.

This study tested the association between periods of cold absolute temperatures over a short period and risk of death by making use of a case-crossover design as we expected cold temperature to be intermittent, and to have an immediate and transient effect.(17) In a case-crossover design each participant serves as his/her own control, which eliminates potential influence of between participant variation. Within this study two control times are supplied by each of the cases themselves, using symmetric bidirectional sampling, i.e. past and future controls, to adjust for possible calendar time trends.(18) We particularly aimed to identify subgroups for whom the relationship between temperature and death was strongest, since these subgroups would contain those most vulnerable.

Measuring temperature, and lag periods

We used daily temperature data from the Met Office. We ensured that data were collated between weather stations within each of the 10 English Strategic Health Authorities (SHAs), so that for any given day, only one value of the relevant weather variable was assigned to every practice and patient within each authority. We chose the station with the overall highest correlation with all other stations within the same SHA. These temperature data were used to calculate the average daily temperature over a lag period. There is no agreement about the lag period of mortality following cold periods, ranging from a few days to 23 days, though a recent systematic review concluded that lags of up to 9 days in exposure to cold temperature intervals were substantially associated with all-cause mortality.(19, 20) In this study, we focus on the impact of the temperature for the date of death and 3 days previously (3-days lag period), assuming that a more immediate impact of temperature is bigger and therefore it may allow for a quicker interventions by GPs. We also used this 3 days lag period for both temperature measures for the 28th day before and the 28th day after the date of death (control dates). We choose the 28^{th} day to adjust for the longer term, season-related effects of temperature so that the effect of the 3-day mean represents a short-term effect only. In a sensitivity analysis we focused on the impact of the temperature based on a 13-days lag period, as suggested by Armstrong(7). The mean and median of the temperature measures are presented in table 1, demonstrating that temperatures were lower on dates of death than on control dates.

HERE Table 1

Effect modifiers

We investigated whether any of the following modified the effect of 3-day temperature: age (categorised as 65-74, 75-84, or 85 and older), living in institution (coded according to whether patients' family ID number appeared more than twice in our CPRD patient file) whose prevalence rises with age (21), quintiles of the 2015 English Indices of Multiple Deprivation (IMD2015) score, calculated at LSOA residence level, house energy efficiency at LSOA level (using percentage of properties at LSOA level with ratings of E, F or G, indicating efficiency lower than 55%), urbanicity (categorised as conurbation, urban or rural), and north/south of England location (south defined as located in the South West, South Central, London, East of England or South East of England SHAs). In addition, from the CPRD immunisation file we identified patients who had undergone their winter flu vaccination (see Supplementary Box 1).

From linked Hospital Episode Statistics, we determined whether an emergency hospital admission occurred two years before death to indicate previous health status. We also determined who was diagnosed with one or more of the following seven chronic conditions: chronic renal disease(22), cancer(23), asthma(22), stroke(24), coronary heart disease(24), diabetes(24), COPD(25) using published clinical code lists as collected in the Manchester Clinical Codes repository.(26)

Statistical methods

Conditional logistic regression models may be applied to these case-crossover data to estimate the odds of exposure to the temperature on the date of death, relative to the odds of exposure to the temperature on the "control" dates. This is equivalent to the odds of death given the temperature on the date of death, compared with that on the control dates. We thus estimated not only the odds ratio (OR) of death associated with 3-day temperature but also interactions between temperature and socio-demographic, medical and house quality characteristics: these interactions were expressed as relative odds ratios (RORs). Since certain causes of death are documented as being responsible for the vast majority of excess winter deaths(27), we focused our second analysis on patients who died in winter of diseases of the circulatory system, respiratory system, nervous system, and mental and behavioural disorders, using the International Classification of Diseases (ICD)-10 classification. Among the 34,777 patients in our study those conditions showed higher death rates in winter than in other seasons (Supplementary table 1).

HERE Tables 2 and 3

Results

537,623 patients within 322 English general practices were eligible in the CPRD source population for linkage to HES and ONS mortality data and aged 65 or older during at least a part of the observation period April 1, 2012 to March 31, 2014. Linkage of ONS mortality data to the study population revealed 34,777 patients aged over 65 who died between April 1, 2012 and March 31, 2014: 6,445 (18.5%) died at the age 65-74, 11,525 (33.1%) at the age 75-84, and 16,807 (48.3%) at the age of 85 and over. This was similar to percentages for all deaths over 65 years' age in England and Wales in 2012-2014, being 19.3%, 34.7%, and 46.0% for the three age groups. After excluding 25 individuals with missing data on deprivation, the total number of deaths used in the analyses was 34,752, of whom 7,710 died during winter months of causes most related to winter mortality (supplementary Table 1). These patients are described in Table 2: Chi-square tests show that those who died in winter due to those causes were more likely to be female, aged over 85, live in institutions, and less likely to have experienced an emergency hospital admission two years prior death or to suffer chronic conditions.

Lower 3-day temperature was associated with higher risk of death (OR 1.001 per 1°C; 95%CI 1.007; 1.015; p<0.001) (Table 3). No interactions were found between temperature measures and age, gender, living in an institution, living in urban/rural areas, living in northern or southern part of England, deprivation level, or house energy efficiency in either unadjusted analyses - containing only the absolute temperature and their interaction with a specific covariate, or adjusted analyses which allowed for interactions between temperature and all covariates simultaneously (Table 4).

We further examined the effect for winter flu vaccination undertaken yearly between September and October .(28) 57% of the patients in this analysis had taken their flu vaccination, which is lower than the 73% for the whole elderly population.(29) Flu vaccination made no impact on protection from cold temperature.

HERE Table 4

When using mean temperature over 13 days prior to the date of death (or equivalent control dates), a similar association was found for absolute temperature (Table 3: OR 1.013 per 1°C; 95%CI 1.008-1.018; p=<0.001). Nearly all interactions between temperature measures and socio-demographic measures were non-significant in both unadjusted and adjusted analysis (Supplementary table 2). Both the unadjusted and the adjusted analysis showed evidence for a stronger effect of low 13-day temperature for patients living in northern part of England (unadjusted ROR northern England: 1.009 per 1°C, 95%CI 0.999-1.019; p=0.084; adjusted ROR 1.010, 95%CI 0.999-1.020, p=0.078, see Supplementary Table 2).

When focusing on patients who died in winter of diseases related to the circulatory system, respiratory system, nervous system, or mental and behavioural disorders, bivariable analyses showed lower 3-day temperature was associated with higher risk of death (OR 1.079 per 1°C; 95%CI 1.067-1.091; p<0.001) (Table 3). There was little evidence of interactions between temperature measures and socio-demographic variables (Table 5), although there was weak evidence for a reduced effect of lower temperature for female patients (adjusted ROR per 1°C for females: 0.980, 95%CI 0.959-1.002, p=0.082), suggesting more impact of 3-day temperature for male patients. Furthermore, there was some evidence of a stronger effect of lower absolute temperatures for patients living in northern part of England in the unadjusted analysis (ROR per 1°C for north England: 1.037, 95%CI 1.013-1.063; p=0.002), and in the adjusted analysis (ROR 1.040 per 1°C, 95%CI 1.013-1.066, p=0.002). Similar associations were found when using mean temperature over 13 days prior to the date of death (or equivalent control dates) (Supplementary Table 3).

HERE Table 5

Discussion

Summary

This analysis of routine medical records held over 300 general practices in England has confirmed that lower temperatures over 3 and 13-day periods were associated with increased risk of death in people aged over 65 years. These effects were particularly marked for deaths occurring in the winter months, for the circulatory and respiratory causes typically associated with excess winter mortality. However, although we found some evidence that patients living in northern parts of England and men were more vulnerable to cold weather, we were unable to demonstrate changes in effects when comparing characteristics such as age, living situation and location, presence of chronic diseases, and average local housing energy efficiency.

Strengths and limitations

This was a large study, including 537,623 patients from 322 practices across England, which are considered broadly representative of all English practices.(15) More than 34,000 deaths were included, making this analysis particularly powerful for investigating interactions, compared with our previous work.(4) We employed a case-crossover analysis, which is particularly powerful for investigating the effect of short term exposures such as low temperature on discrete outcomes, and is free of confounding effects of between-person variables.(17, 18) Any interactions detected however would not carry this advantage. The study used a wide range of covariates, including socio-demographic, geographic, medical and house quality characteristics, although marital status could not be included due to many missing data in CPRD. Our study focussed on recent winters of 2012/13 and 2013/14, but the winter 2013/14 showed the lowest number of excess winter deaths since records began in 1950/51(27), making it harder to detect associations.

It is possible that reasons for winter deaths may lie outside purely medical explanations. In particular, improvements to housing through insulation or servicing of boilers, more suitable clothing or heating in cold weather, and property characteristics such as constructing and age(30) may carry more influence. Our study included a measure of energy efficiency in homes in the patient's LSOA – this however was of limited value since it could not be attributed to an individual patient's home condition. Furthermore, energy performance data only exist for properties when constructed, sold or let, in particular those which have been on the property market since 2010: relevant data may therefore be particularly lacking for people aged over 65, and explain the lack of association with temperature related mortality in our analysis.

Our study investigated differences in *relative* risk between subgroups of patients, but in the absence of differences in relative risk, it is still likely that those who are constantly at high risk (such as the very elderly) will show the greatest increase in *absolute* risk during periods of cold weather.

Comparison with existing literature

Some ecological studies in Great Britain investigated the relationship between excess winter mortality and deprivation, and found a weak or no association (8-11), in line with our results. Aylin et al. concluded from an ecological study that lack of central heating was significantly associated with dying in winter(11), though Wilkinson et al. found no association between difficulties in keeping the house warm and vulnerability to winter mortality in their cohort study(7), in line with our results using an average house energy efficiency measure. Furthermore, Wilkinson et al. found little evidence for differences between regions, age groups, and markers for illness such as shortness of breath, depression or taking more than five medications, but found some evidence of increased vulnerability for women and patients with pre-existing respiratory illness.(7) Similar to Wilkinson et al. our results showed no differences between age groups. However, we found some evidence of less impact of low temperature for women in winter for causes typically associated with excess winter mortality, but we didn't find associations for patients with previous emergency admission(s) and patients with chronic conditions. Hajat et al. observed little modification of the cold effect by gender in their ecological study, but did find people in nursing and care homes were more vulnerable to both hot and cold weather.(8) Our study didn't find an association between living in institutions and risk of death related to cold weather.

Implications for research and/or practice

We have not found evidence to support the use of existing data in medical records to identify those at increased risk of death during cold periods, leaving GPs without the necessary tools to implement NICE recommendations. Alternatively, GPs or general practices might identify vulnerable patients by communication with other medical staff to increase knowledge about patients, so-called team-based continuity of care, or by improving access and use of comprehensive information about patient's previous health care encounters for providers caring for a patient, so-called informational continuity.

It has been demonstrated that although individual days which are exceptionally cold carry the highest risk, such days are rare, and that the majority of deaths due to cold weather are attributable to moderate cold rather than severe cold.(2) If public health interventions or advice to patients are geared only to self-care on the coldest days, little impact will be made on the burden of excess winter mortality. Population level interventions which focus on the effects of moderate cold are most likely to decrease burden in the population and the need for emergency medical care. Evaluative studies of innovations in building designs are required, at the same time that such innovations are occurring, or of retrospective improvements of older housing stock.

Conclusion

The present study provides no evidence that GPs can easily identify those at risk during cold periods from data available in existing electronic records. Alternative methods are needed if GPs are to be equipped to operationalise NICE recommendations.

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References

1. Fowler T, Southgate RJ, Waite T, et al. Excess winter deaths in Europe: a multi-country descriptive analysis. Eur J Public Health. 2015;25(2):339-45.
2. Gasparrini A, Guo Y, Hashizume M, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet. 2015.
3. Healy JD. Excess winter mortality in Europe: a cross country analysis identifying key risk factors. J Epidemiol Community Health. 2003;57(10):784-9.
4. Sartini C, Barry SJ, Wannamethee SG, et al. Effect of cold spells and their modifiers on cardiovascular disease events: Evidence from two prospective studies. Int J Cardiol. 2016;218:275-83.
5. Marmot Review Team. The health impacts of cold homes and fuel poverty. London; 2011.
6. Wilkinson P, Landon M, Armstrong B, et al. Cold comfort: the social and environmental determinants of excess winter death in England, 1986-1996: Joseph Rowntree Foundation; 2001.
7. Wilkinson P, Pattenden S, Armstrong B, et al. Vulnerability to winter mortality in elderly people in Britain: population based study. BMJ. 2004;329(7467):647.
8. Hajat S, Kovats RS, Lachowycz K. Heat-related and cold-related deaths in England and Wales: who is at risk? Occupational and Environmental Medicine. 2007;64(2):93-100.
9. Lawlor DA, Harvey D, Dews HG. Investigation of the association between excess winter mortality and socio-economic deprivation. Journal of Public Health. 2000;22(2):176-81.
10. Stacey D, Pritchard C. An ecological study of excess winter mortality in England and deprivation. Public Health. 2016;141:207-9.
11. Aylin P, Morris S, Wakefield J, et al. Temperature, housing, deprivation and their relationship to excess winter mortality in Great Britain, 1986–1996. Int J Epidemiol. 2001;30(5):1100-8.
12. National Institute for Health and Care Excellence (NICE). Excess winter deaths and illness and the health risks associated with cold homes. NG6. London; 2015.
13. Kmietowicz Z. GPs should identify and visit people at risk from cold homes, says NICE. BMJ: British Medical Journal (Online). 2015;350.
14. Gordon D, Bone A, Pebody R, de Lusignan S. The GP's role in promoting winter wellness. Br J Gen Pract. 2017:52-3.
15. Herrett E, Gallagher AM, Bhaskaran K, et al. Data Resource Profile: Clinical Practice Research Datalink (CPRD). Int J Epidemiol. 2015;44(3):827-36.
16. Williams T, Van Staa T, Puri S, Eaton S. Recent advances in the utility and use of the General Practice Research Database as an example of a UK Primary Care Data resource. Therapeutic advances in drug safety. 2012;3(2):89-99.
17. Maclure M. The case-crossover design: a method for studying transient effects on the risk of acute events. Am J Epidemiol. 1991;133(2):144-53.
18. Maclure M, Mittleman, MA. Should we use a case-crossover design? Annu Rev Public Health. 2000;21(1):193-221.
19. Monteiro A, Carvalho V, Góis J, Sousa C. Use of "Cold Spell" indices to quantify excess chronic obstructive pulmonary disease (COPD) morbidity during winter (November to March 2000–2007): case study in Porto. Int J Biometeoro. 2013;57(6):857-70.
20. Yu W, Mengersen K, Wang X, et al. Daily average temperature and mortality among the elderly: a meta-analysis and systematic review of epidemiological evidence. Int J Biometeoro. 2012;56(4):569-81.
21. ONS. Changes in the older resident care home population between 2001 and 2011, Office for National Statistics (ONS). London; 2014.
22. Doran T, Kontopantelis E, Valderas JM, et al. Effect of financial incentives on incentivised and non-incentivised clinical activities: longitudinal analysis of data from the UK Quality and Outcomes Framework. Bmj. 2011;342:d3590.

23. Reeves D, Springate DA, Ashcroft DM, et al. Can analyses of electronic patient records be independently and externally validated? The effect of statins on the mortality of patients with ischaemic heart disease: a cohort study with nested case–control analysis. BMJ open. 2014;4(4):e004952.

24. Kontopantelis E, Springate D, Reeves D, et al. Withdrawing performance indicators: retrospective analysis of general practice performance under UK Quality and Outcomes Framework. Bmj. 2014;348:g330.

25. Reilly S, Olier I, Planner C, et al. Inequalities in physical comorbidity: a longitudinal comparative cohort study of people with severe mental illness in the UK. BMJ Open. 2015;5(12):e009010.

26. Springate DA, Kontopantelis E, Ashcroft DM, et al. ClinicalCodes: an online clinical codes repository to improve the validity and reproducibility of research using electronic medical records. PloS One. 2014;9(6):e99825.

27. ONS. Statistical bulletin. Excess Winter Mortality in England and Wales, 2013-14 (Provisional) and 2012-13 (Final). London: Office for National Statistics; 2014.

28. Department of Health. Seasonal Flu Plan 2012/13. London; 2012.

29. Health and Social Care Information Centre (HSCIC). NHS Immunisation Statistics, England 2012-13. 2013.

30. Oreszczyn T, Hong SH, Ridley I, et al. Determinants of winter indoor temperatures in low income households in England. Energy and Buildings. 2006;38(3):245-52.

Table 1: Distribution of temperature measures around dates of death, and 28 days before and after deaths

Temperature	Mean (Median, Interquartile range)	
	Whole study period	Wintertime within study period[1]
Absolute daily mean temperature in degree Celsius, 3-days lag period, 28th day before death	9.623 (8.775, 6.000- 13.800)	5.492 (5.900, 4.100-7.325)
Absolute daily mean temperature in degree Celsius, 3-days lag period, date of death	9.543 (8.700, 5.875-13.675)	5.111 (5.450, 3.325-7.125)
Absolute daily mean temperature in degree Celsius, 3-days lag period, 28th day after death	9.669 (9.125, 5.950-13.700)	5.738 (5.875, 3.425-8.075)
Absolute daily mean temperature in degree Celsius, 13-days lag period, 28th day before death	9.630 (8.779, 6.029-13.736)	5.673 (5.986, 4.443-7.064)
Absolute daily mean temperature in degree Celsius, 13-days lag period, date of death	9.552 (8.700, 5.982-13.614)	5.168 (5.457, 3.586-6.707)
Absolute daily mean temperature in degree Celsius, 13-days lag period, 28th day after death	9.665 (9.143, 6.036-13.664)	5.649 (5.879, 3.564-7.457)

[1] months December-March between 1/04/2012 and 31/03/2014.

Table 2: Characteristics of 34,752 patients who died and used in case-crossover analysis

Patient characteristic	**No. (%) died between 1/4/2012 and 31/3/2014**	**No. (%) died in winter months (Dec-Mar) between 1/4/2012 and 31/3/2014 due to diseases of the circulatory system, respiratory system, nervous system, or mental and behavioural disorders**	**No. (%) died in other seasons and/or due to other diseases**
Gender			
Male	16,043 (46.2)	3,337 (43.3)	12,706 (47.0%)
Female	18,709 (53.8)	4,373 (56.7)	14,336 (53.0%)
Age died			
65-74	6,442 (18.5)	920 (11.9)	5,522 (20.4%)
75-84	11,516 (33.1)	2,400 (31.1)	9,116 (33.7%)
85+	16,794 (48.3)	4,390 (57.0)	12,404 (45.9%)
Living situation			
Community	31,671 (91.1)	6,833 (88.6)	24,838 (91.9%)
Institution	3,081 (8.9)	877 (11.4)	2,204 (8.1%)
Location			
Urban conurbation	10,583 (30.5)	2,339 (30.3)	8,244 (30.5%)
Cities and towns	20,198 (58.1)	4,496 (58.3)	15,702 (58.1%)
Rural	3,971 (11.4)	875 (11.4)	3,096 (11.4%)
Deprivation level (IMD)			
Q1 (least deprived)	7,217 (20.8)	1,555 (20.2)	5,662 (20.9%)
Q2	8,051 (23.2)	1,756 (22.8)	6,285 (23.3%)
Q3	7,473 (21.5)	1,704 (22.1)	5,769 (21.3%)
Q4	6,362 (18.3)	1,435 (18.6)	4,927 (18.2%)
Q5 (most deprived)	5,649 (16.3)	1,260 (16.3)	4,389 (16.2%)
House energy efficiency			
Q1 (lowest inefficiency)	5,206 (15.0)	1,173 (15.2)	4,033 (14.9%)
Q2	8,115 (23.4)	1,813 (23.5)	6,302 (23.3%)
Q3	8,216 (23.6)	1,821 (23.6)	6,395 (23.7%)
Q4	7,845 (22.6)	1,731 (22.5)	6,114 (22.6%)
Q5 (highest inefficiency)	5,370 (15.5)	1,172 (15.2)	4,198 (15.5%)
Emergency hospital admission within 2 years of death			
No	6,081 (17.5)	1,575 (20.4)	4,506 (16.7%)
Yes	28,671 (82.5)	6,135 (79.6)	22,536 (83.3%)
Chronic condition(s)[1]			
No	21,259 (61.2)	5,601 (72.7)	15,658 (57.9%)
Yes	13,493 (38.8)	2,109 (27.3)	11,384 (42.1%)
Region			
South	11,593 (33.4)	2,593 (33.6)	9,000 (33.3%)
North	23,159 (66.6)	5,117 (66.4)	18,042 (66.7%)
Total	34,752 (100.0)	7.710 (100.0)	27,042 (100.0%)

[1]Diagnosed with one or more of the following seven chronic conditions: chronic renal disease, cancer, asthma, stroke, coronary heart disease, diabetes, or COPD.

Table 3: Main effects from a univariable analysis of relationship between 1°C fall in average temperature in degrees Celsius (3-days lag period)[1] and death (odds ratios (p-value)), using 28th day before and after date of death as control days.

	3-days lag			13-days lag		
	OR	95%CI	p	OR	95%CI	p
Overall	1.011	1.007; 1.015	<0.001	1.013	1.008; 1.018	<0.001
Winter time[2]	1.079	1.067; 1.091	<0.001	1.138	1.121; 1.155	<0.001

[1] Based on temperatures of date of death and 3 days previous (case day), and 28th day before date of death and 3 days previous and 28th day after date of death and 3 days previous (control days).

[2] Those who died in the months December-March of diseases of the circulatory system, respiratory system, nervous system, or mental and behavioural disorders.

Table 4: Unadjusted and adjusted interaction effects with average temperature fall per 1 degree Celsius (3-days lag period)[1] on death among patients aged 65 or older who died in the financial years 2012/13-2013/14 (N=34,752 deaths).

		Unadjusted			Adjusted		
	OR[2]	ROR[3]	95% CI	P-value	ROR	95% CI	P-value
Temperature*gender (ref.=male)	1.012						
Female	1.009	0.997	0.989; 1.005	0.474	0.996	0.996; 1.005	0.420
Temperature*age died (ref.=65-74)	1.011						
75-84	1.010	0.999	0.987; 1.011	0.877	1.000	0.987; 1.012	0.937
85+	1.011	1.001	0.989; 1.012	0.901	1.002	0.991; 1.014	0.696
Temperature*community (ref.) or institution	1.012						
Institution	1.003	0.992	0.978; 1.006	0.263	0.990	0.976; 1.006	0.220
Temperature*urban (ref.=urban conurbation)	1.013						
Cities and towns	1.010	0.997	0.988; 1.006	0.531	1.000	0.990; 1.010	0.990
Rural	1.009	0.996	0.982; 1.011	0.637	0.998	0.982; 1.014	0.791
Temperature*IMD (ref.=Q1)	1.008						
Q2	1.011	1.003	0.991; 1.016	0.586	1.003	0.991; 1.015	0.614
Q3	1.010	1.002	0.989; 1.015	0.738	1.002	0.989; 1.015	0.753
Q4	1.011	1.003	0.990; 1.017	0.616	1.003	0.990; 1.017	0.637
Q5 (most deprived)	1.015	1.007	0.993; 1.020	0.346	1.005	0.991; 1.020	0.478
Temperature*house energy efficiency(ref.=Q1)	1.009						
Q2	1.013	1.003	0.989; 1.017	0.659	1.004	0.990; 1.018	0.553
Q3	1.009	1.000	0.986; 1.014	0.988	1.001	0.987; 1.015	0.856
Q4	1.009	0.999	0.985; 1.013	0.914	1.001	0.987; 1.016	0.857
Q5 (highest inefficiency)	1.014	1.005	0.989; 1.020	0.550	1.007	0.991; 1.025	0.374
Temperature*emergency admission (ref.=no)	1.017						
Yes	1.010	0.993	0.982; 1.004	0.220	0.992	0.981; 1.003	0.164
Temperature*chronic conditions[4] (ref.=no)	1.012						
Yes	1.009	0.997	0.988; 1.005	0.467	0.997	0.988; 1.005	0.468
Temperature*north/south divide (ref.=south)	1.008						
North	1.016	1.008	0.999; 1.017	0.100	1.008	0.998; 1.017	0.118

[1] Based on temperatures of date of death and 3 days previous (case day), and 28th day before date of death and 3 days previous and 28th day after date of death and 3 days previous (control days).

[2] Odds ratio per 1-degree Celsius fall in temperature.

[3] Relative odds ratio to indicate modifying effect of factor to temperature: e.g. for gender: odds ratio for females divided by odds ratio for males: ROR female=1.009/1.012=0.997.

[4] Diagnosed with one or more of the following seven chronic conditions: chronic renal disease, cancer, asthma, stroke, coronary heart disease, diabetes, or COPD.

*=interaction, OR=Odds Ratio, CI=Confidence Interval, ROR=Relative Odds Ratio, ref.=reference

Table 5: Unadjusted and adjusted interaction effects with average temperature fall per 1 degree Celsius (3-days lag period)[1] on death among patients aged 65 or older who died in winters of the financial years 2012/13-2013/14 due to diseases of the circulatory system, respiratory system, nervous system, or mental and behavioural disorders (N=7,710 deaths).

	Unadjusted				Adjusted		
	OR[2]	ROR[3]	95% CI	P-value	ROR	95% CI	P-value
Temperature*gender (ref.=male)	1.090						
Female	1.070	0.982	0.962; 1.003	0.091	0.980	0.959; 1.002	0.082
Temperature*age died (ref.=65-74)	1.075						
75-84	1.079	1.004	0.969; 1.041	0.820	1.006	0.971; 1.044	0.729
85+	1.079	1.004	0.972; 1.038	0.795	1.012	0.978; 1.048	0.488
Temperature*community (ref.) or institution	1.080						
Institution	1.067	0.987	0.955; 1.019	0.431	0.989	0.956; 1.022	0.516
Temperature*urban (ref.=urban conurbation)	1.096						
Cities and towns	1.068	0.975	0.951; 0.998	0.036	0.984	0.959; 1.010	0.227
Rural	1.088	0.993	0.956; 1.031	0.700	0.989	0.950; 1.030	0.592
Temperature*IMD (ref.=Q1)	1.080						
Q2	1.092	1.011	0.979; 1.045	0.493	1.012	0.979; 1.046	0.488
Q3	1.074	0.994	0.962; 1.028	0.740	0.997	0.964; 1.030	0.820
Q4	1.066	0.987	0.953; 1.021	0.448	0.988	0.953; 1.024	0.497
Q5 (most deprived)	1.079	0.999	0.963; 1.035	0.956	0.992	0.955; 1.031	0.685
Temperature*house energy efficiency(ref.=Q1)	1.069						
Q2	1.076	1.006	0.972; 1.043	0.718	1.012	0.978; 1.049	0.494
Q3	1.074	1.004	0.969; 1.041	0.808	1.008	0.973; 1.046	0.645
Q4	1.079	1.010	0.975; 1.046	0.598	1.013	0.977; 1.052	0.486
Q5 (highest inefficiency)	1.099	1.028	0.989; 1.068	0.167	1.027	0.984; 1.071	0.215
Temperature*emergency admission (ref.=no)	1.093						
Yes	1.075	0.983	0.959; 1.010	0.221	0.979	0.953; 1.006	0.132
Temperature*chronic conditions[4] (ref.=no)	1.079						
Yes	1.077	0.998	0.975; 1.022	0.894	0.999	0.975; 1.024	0.917
Temperature*north/south divide (ref.=south)	1.067						
North	1.108	1.038	1.013; 1.063	0.002	1.040	1.013; 1.066	0.002

[1] Based on temperatures of date of death and 3 days previous (case day), and 28th day before date of death and 3 days previous and 28th day after date of death and 3 days previous (control days).

[2] Odds ratio per 1-degree Celsius fall in temperature.

[3] Relative odds ratio to indicate modifying effect of factor to temperature: e.g. for gender: odds ratio for females divided by odds ratio for males: ROR female=1.070/1.090=0.982.

[4] Diagnosed with one or more of the following seven chronic conditions: chronic renal disease, cancer, asthma, stroke, coronary heart disease, diabetes, or COPD.

*=interaction, OR=Odds Ratio, CI=Confidence Interval, ROR=Relative Odds Ratio, ref.=reference