Cold comfort

The social and environmental determinants of excess winter deaths in England, 1986–96

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Contents

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This report is based on work carried out by a research team at the London School of Hygiene and Tropical Medicine. The team members and their individual contributions were as follows:

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Glossary

Ambient temperature	Temperature of the surroundings – mainly used to refer to outdoor temperature in this report.
Cardiovascular disease	Diseases of the heart and circulation. The principal cardiovascular conditions leading to mortality are heart attacks and strokes.
95% Confidence interval	The range of values within which the true value of a variable of interest is likely to lie (with 95% probability). The confidence interval reflects the uncertainty around estimates of risk obtained from data analysis, and shows this by a range for the true value rather than a single estimate.
EHCS	English House Condition Survey, a periodic survey of dwellings in England conducted by the Department of the Environment, Transport and the Regions (now the Department of Transport, Local Government and the Regions).
EWDI	Excess winter deaths index. The percentage excess of deaths for the four winter months (December to March) compared with the average for the other months of the year.
Epidemiology	The study of the incidence and distribution of diseases; a branch of medical research concerned with analysing statistics on disease occurrence in population groups.
Logarithmic scale	A logarithm is the power to which a fixed number ('the base') must be raised to produce a given number. For example, the logarithm of 1,000 to base 10 is 3. A *logarithmic scale* is one in which evenly-spaced intervals represent such a power scale: for example, 10, 100, 1,000, 10,000...
P-value	Is a measure of how likely it is that the observed difference between groups could have occurred by chance if in fact there is no true difference between them. The smaller the p-value, the less likely it is that the observed difference could be a chance occurrence. By convention, probabilities less than 0.05 are said to be 'statistically significant'. This corresponds to a probability of less than 1 in 20 that the observed difference could have occurred by chance.
Risk	The probability (chance) of disease occurring in people who are previously free of disease. For example, a risk of 0.2 means that disease was observed or expected to occur in 20% of previously disease-free people.

Relative risk	The multiple by which the risk (probability) of disease is increased by some risk factor. For example, a relative risk of death of 1.2 associated with cold means that those exposed to cold are 1.2 times more likely to die in a given period than those not exposed to cold. This is equivalent to an *excess risk* of 20%.
Respiratory disease	Disease of the lungs and airways. It includes asthma, chronic bronchitis, emphysema and pneumonia.
Time-series (analysis)	Analysis of variation in disease and its causes over time. In this report this means analyses of the daily fluctuation in number of deaths in relation to daily fluctuation in maximum daily temperature.
SAP rating	Standard Assessment Procedure rating. An index (measured on a logarithmic scale) that reflects the cost of heating unit floor area under a standard heating regime. The scale ranges from 1 (highly inefficient) to 100 (highly efficient). The index depends on the rate of heat loss from the dwelling, determined by building fabric, degree of insulation, ventilation, and the cost of supplying heat, determined by heating efficiency, fuel price, and solar gain. It is *not* affected by characteristics of the household occupying the dwelling (such as, household size, heating patterns, temperatures).
Socioeconomic group	The group to which an individual belongs by virtue of his or her social and economic position – usually classified on the basis of occupation. Groups are typically defined to reflect a broad ranking of income and 'social status': for example, professional groups, managers, non-manual workers, skilled manual workers, semi-skilled workers and unskilled workers.

Summary

Background

In Britain there are around 40,000 more deaths during winter months (December to March) than expected from deaths rates in other months of the year. Much of the seasonal increase is due to a rise in deaths from cardiovascular and respiratory disease. Although influenza, respiratory infections and other seasonal factors may account for part of the winter excess in mortality, around two thirds of it can be attributed to the effects of cold.

The winter excess is greater than in most other countries of continental Europe and Scandinavia, despite the fact that Britain has comparatively mild winters. A partial explanation may lie in the quality of our housing stock, which is less thermally efficient than that in most other north European countries and hence may afford less protection against the cold.

In the study reported here, data on housing conditions from a large national survey were coupled with routine mortality statistics to examine whether vulnerability to winter death is related to housing quality and home heating.

Methods

Analysis of 80,331 deaths from cardiovascular disease in England, 1986-96, linked by postcode of residence to data from the 1991 English House Condition Survey (DoE, 1993).

Results

Overall, deaths from cardiovascular disease were 22.9% higher in the winter months (December to March) than in other months of the year. The percentage of winter excess varied little by region or socioeconomic group, but rose steeply with age. Statistically significant excesses of winter death were seen with age of the property (28.2% winter excess in properties built before 1850 compared to 15.0% in properties built after 1980) and with poorer thermal efficiency ratings. A strong association was also seen with lower indoor temperatures: the coldest homes had a risk around 20% greater than that of the warmest homes.

Analyses of variation in indoor temperature showed that there was significant variation in indoor temperature by geographical region (coolest homes in the West Midlands, warmest in London), but the main determinants of low indoor temperatures were age of property, absence of central heating, dissatisfaction with the heating system, cost of heating the dwelling to a minimum standard, small household size and low net income. Housing tenure, being on state benefits, and having a poor thermal efficiency rating, were not strongly associated with indoor temperature after adjustment for these factors, although individually they were each important determinants of indoor temperature. Unsurprisingly, the disadvantage of having a difficult-to-heat home was found to be greater in those households with low incomes, presumably because they are unable to afford the energy expenditure needed to maintain an adequate indoor temperature.

Analysis of the daily pattern of deaths showed that the marked seasonal fluctuation was considerably larger in homes that were expensive to heat compared with those that were inexpensive to heat. Overall, mortality was found

to rise by around 2% for each degree Celsius fall in outdoor temperature below 19°Celsius. The increase in mortality with cold was greater in homes predicted to have comparatively low indoor temperatures, although the variation between the warmest and coldest houses was fairly small. The nature of the study means that misclassifcation of the temperature characteristics of dwellings is inevitable, and this is likely to lead to underestimation of the influence of home heating on the temperature–mortality relationship.

Conclusions

The results suggest that indoor temperature and markers of thermal efficiency of dwellings, including property age, are associated with increased vulnerability to winter death from cardiovascular disease. Although not conclusive, these findings suggest that substantial public health benefits can be expected from measures that improve the thermal efficiency of homes and the affordability of heating them. Evaluations now beginning of the government's Home Energy Efficiency Scheme should provide direct evidence on this. Wider debate is needed to consider the forms of housing, energy and social policy that are likely to deliver the greatest public health benefits in relation to winter death.

1

Introduction

Background

Britain has a large seasonal fluctuation in mortality. In the months of December to March there are around 40,000 more deaths than expected from the death rates in other months of the year – a winter excess of some 20% (Curwen, 1990/91). This is a greater winter rise in mortality than in most neighbouring countries of continental Europe and Scandinavia, despite the fact that Britain has comparatively mild winters (McKee, 1989). The excess:

- is greatest for cardiovascular and respiratory mortality;
- is due, in part, to seasonal fluctuations in respiratory infection and other risk factors; but
- is mainly attributable to changes in ambient temperature, at least in years without influenza epidemics.

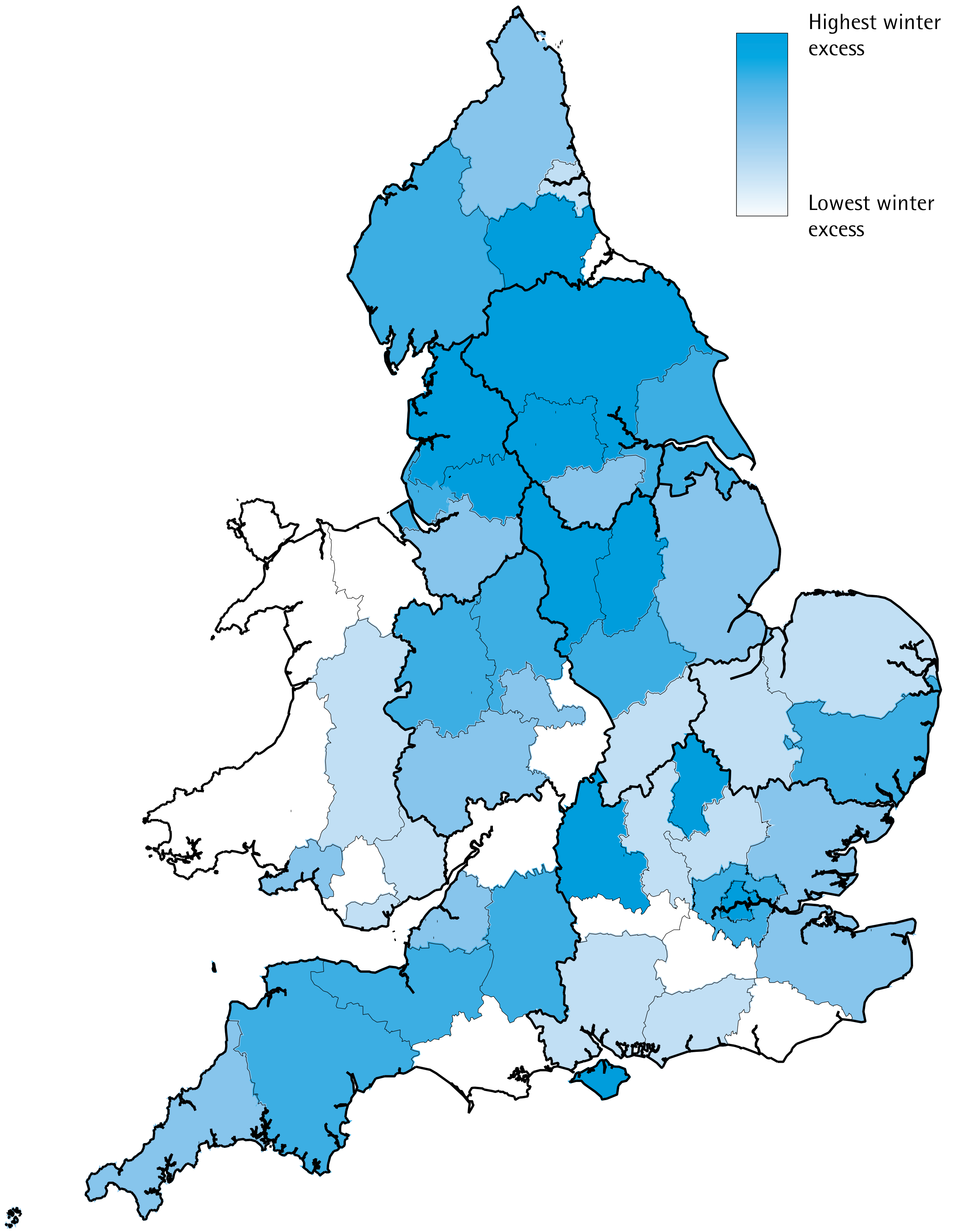
Why Britain has so large a seasonal swing in mortality is unclear, especially given that cold-exposure appears to be a major determinant of it (Donaldson and Keatinge, 1997). Britain is buffered against severe cold by the Gulf Stream and surrounding seas, and we do not experience the severe winters of neighbouring countries that have much smaller winter excesses of mortality. The contrast with Scandinavia, where there is only a modest winter increase in deaths despite harsh winters, is particularly striking.

Keatinge and others (Eurowinter-Group, 1997) found that, across Europe, cold-related mortality is greater in regions with warm winters, and in populations who appear to take fewer precautions to protect themselves against the cold. Although many factors contribute, one of the important determinants of excess winter mortality may be the adequacy of indoor heating.

Compared with most other north European countries, British housing has low thermal efficiency. It thus offers poorer protection against cold and is comparatively expensive to heat. Hence, despite having a mild winter climate, indoor temperatures in British homes often fall to levels that may well have adverse health effects, especially for vulnerable groups such as people over 65 years of age. Older people, in particular, spend a very high fraction of their time indoors at home, so most of their exposure to cold is determined by the temperature of the living and sleeping spaces in their own homes. The temperatures recorded in some homes are certainly low enough to have adverse effects on health.

As yet, however, there is limited evidence to link housing with excess winter death, although geographical studies in England and Wales have indicated that excess winter death is related to the proportion of homes without central heating. As Figure 1 shows, there is a slightly greater winter excess of deaths in northern England compared with more southern counties, which could reflect the slightly colder winter temperatures in northern England, although there are other explanations which could account for this geographical pattern.

Figure 1: Percentage excess in winter deaths (age-adjusted) by county



Temperature–mortality relationship

Much of the epidemiological evidence about the health effects of low temperatures comes from analyses of the day-to-day variation in mortality in relation to measured outdoor temperature. Figure 2 shows a time-series analysis of deaths in London over an 11-year period. Deaths on individual days are plotted as points, but the continuous line represents a two-month moving average as an indication of the underlying seasonal fluctuation. The amplitude of the winter–summer difference is clear. In fact, based on the two-month average, the winter peak of mortality is more than 40% higher than the summer trough. This is a remarkable difference when one considers that this is the pattern averaged across all ages and all causes of death.

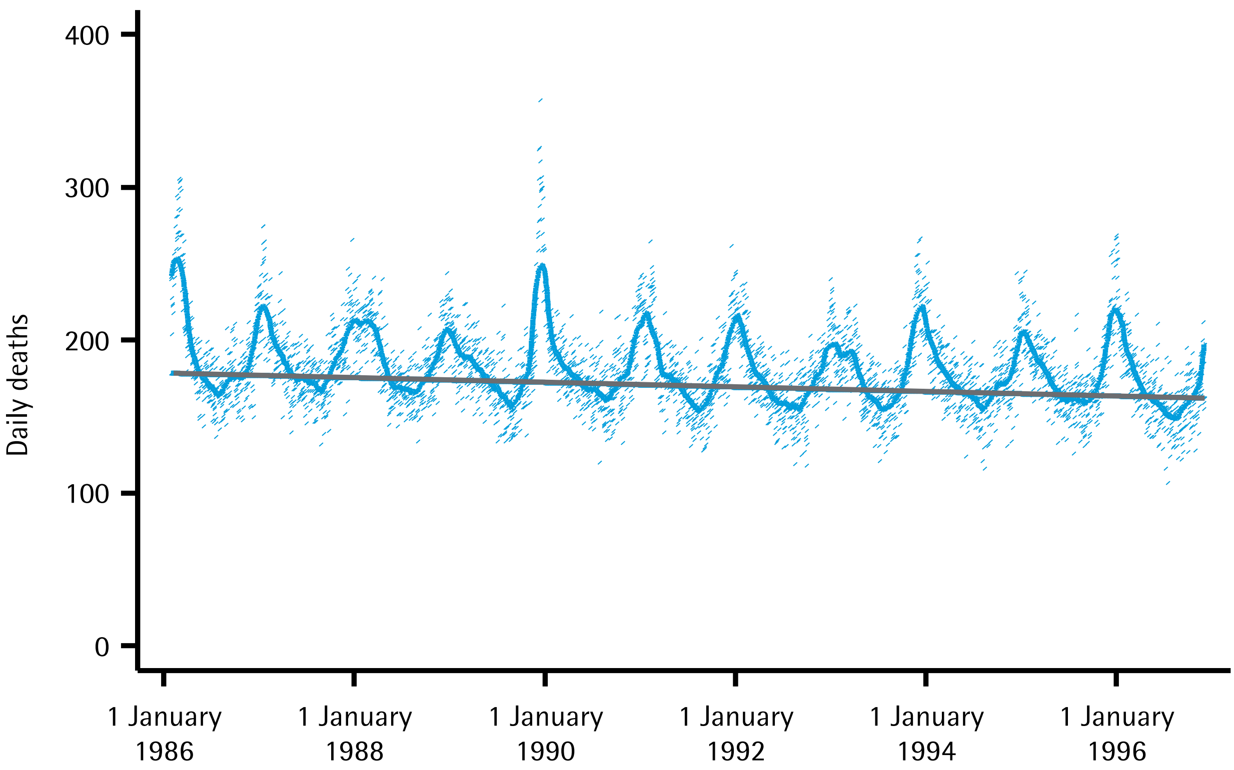
This pattern also shows that the conventional definition of excess winter death – the percentage by which the mortality rate for the period December to March exceeds that of other months of the year – does not reflect the true magnitude of variation in death rates across the year. The oft-quoted 20% figure is one which derives from an arbitrary definition of winter based on calendar months. It underestimates the true seasonal fluctuation.

As will be seen later, when mortality is analysed in relation to daily temperature it is found that:

- the relationship is U-shaped, with deaths rising at low outdoor temperatures and also on days of high temperature;
- at temperatures below 20°C (degrees Celsius) maximum daily temperature, mortality increases with each degree Celsius fall in outdoor temperature.

Thus, it is not just the very coldest days that are associated with higher death rates; an increase above the minimum daily mortality rate is apparent even at quite moderate falls in temperature. At the highest ambient temperatures the increase in deaths is mainly attributable to the effects of heat stress on the cardiovascular system.

Figure 2: Seasonal fluctuations in deaths, London (1986–96)



The large number of excess winter deaths reflects the fact that seasonal factors have a substantial impact on the common causes of death. In routine statistics very few winter deaths are directly attributed to cold – very few, for example, are recorded as due to hypothermia. Most of the excess is from causes such as heart disease, strokes and respiratory illness, which are the commonest causes of death throughout the year.

In summary, in Britain we have a large winter excess of deaths – primarily from cardiorespiratory causes – much of which appears to be attributable to exposure to cold. On strong theoretical grounds, and from limited epidemiological evidence, it is probable that inadequate home heating contributes to vulnerability to cold-related death. Hitherto, there has been no direct evidence of this, but the importance to public policy of establishing such a link is clear. This was the aim of the study reported here.

About the study

The study had two principal objectives:

1. to quantify the relationship between housing quality (including energy efficiency), socioeconomic status and excess winter mortality;
2. to examine whether the relationship between daily mortality and low outdoor temperature is modified by housing conditions.

It was based on linkage of two main data sets: the Energy Report of the 1991 English House Conditions Survey (EHCS) (DoE, 1996) conducted by the Department of the Environment (DoE; now the Department for Environment, Food and Rural Affairs); and mortality data for England, 1986-96, supplied by the Office for National Statistics (ONS). Records in the two data sets were linked by postcode of residence.

The EHCS therefore provided detailed information on the heating and other characteristics of a large, random sample of homes across England. Our study related these characteristics to mortality at postcodes where at least one dwelling had been surveyed. The study had three components (see Figure 3):

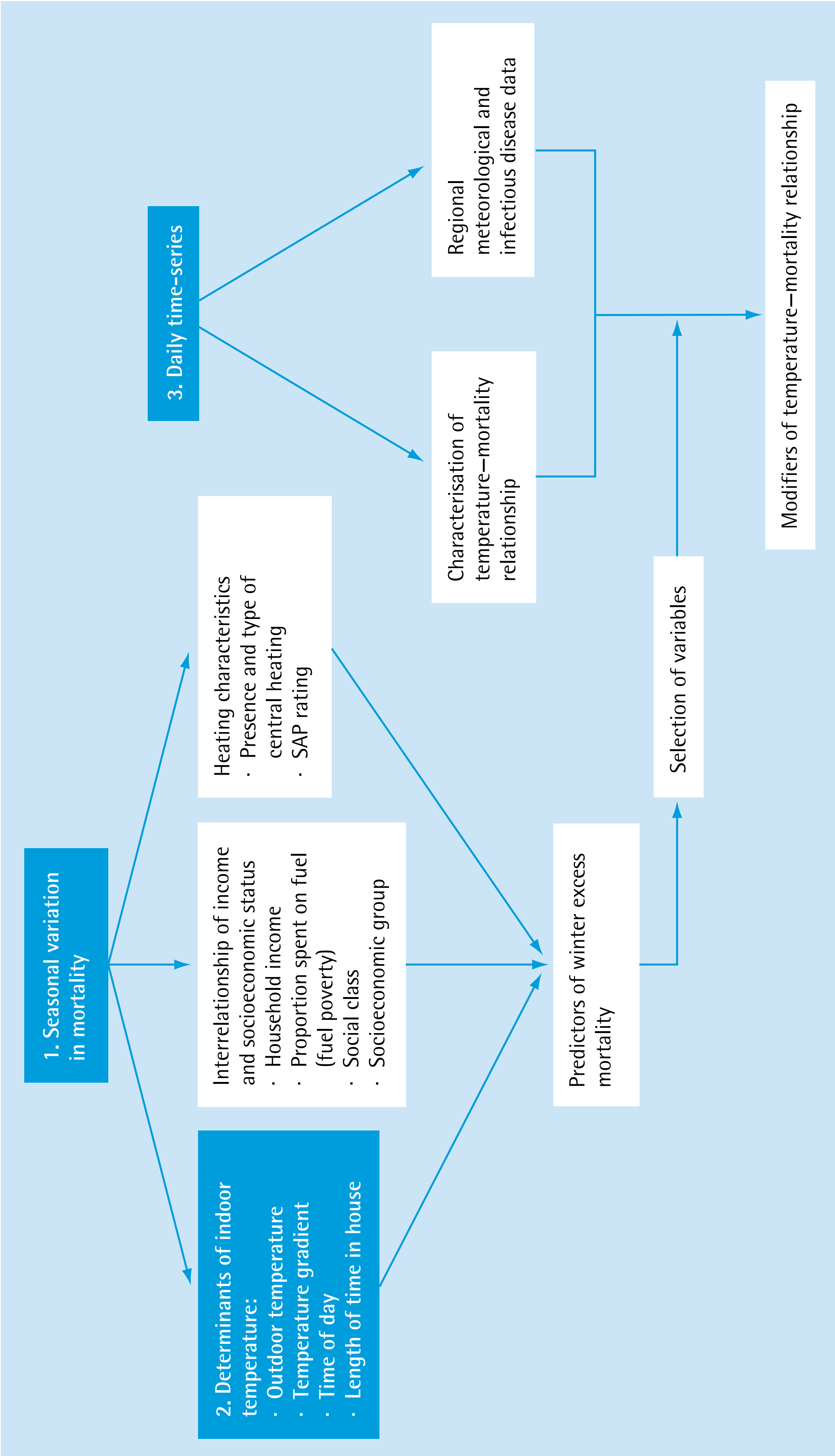
- a seasonal analysis of excess winter mortality;
- an analysis of the determinants of indoor temperature;
- a daily time-series analysis, which examined whether housing and other factors influence the relationship between outdoor temperature and mortality.

Structure of the report

The chapters that follow consider in turn each of the three parts of the analysis: seasonal mortality, the determinants of indoor temperature and the association between outdoor temperature and mortality. The report concludes with a discussion of the interpretation of the results of these analyses and their implications for public health policy.

For clarity, many of the technical details of the analyses have been omitted. These and results of further analyses can be obtained from the authors on request (email: paul.wilkinson@lshtm.ac.uk, tel: 020 7927 2103).

Figure 3: Project outline



2

Analysis and results

Seasonal mortality

The seasonal analysis was based on the excess winter death index (EWDI) as the measure of seasonal risk. The EWDI is defined as the percentage of excess deaths for the four winter months compared with the average of the other months of the year. The main research questions were how the winter rise in mortality related to:

- socioeconomic status;
- dwelling characteristics, especially thermal efficiency and heating facilities;
- indoor temperature and its determinants.

The final analysis was based on data for 21,173 dwellings with full or partial housing surveys under the 1991 EHCS, to which 179,234 death records were linked by postcode of residence (Figure 4). The study focused on mortality from cardiovascular disease as cardiovascular disease has the clearest relationship to ambient temperature.

Table 1 shows the results of tabulating percentage excess winter death against personal and housing characteristics. Over all ages and the study period as a whole, there were 80,331 deaths from cardiovascular disease, of which 30,467 were in winter months – a winter excess of 22.9%. The percentage rose steeply with age to 30% in the 85+ age group. Women had a slightly higher risk than men, but this excess disappeared after adjusting for age.

There was modest variation by region (p=0.06), and no obvious north–south trend. The lowest winter excess was in the eastern region (17.9%) and the highest in the East Midlands (30.4%). After adjusting for age, gender and socioeconomic status, there was 13% variation between the lowest (Greater London) and highest (West Midlands) regions.

There was also little variation by socioeconomic group of the head of household either before or after adjustment for age and gender. In fact, professionals had the highest point estimate of excess winter death and unskilled workers the lowest, although the trend across socioeconomic groups was not statistically significant.

There was also a weak trend with housing tenure, with lowest risk in housing association and local authority dwellings, and highest risk in those in privately rented accommodation and owner-occupied dwellings. Age of property had a strong association with excess winter death, with a fairly steady decline in risk from pre-1850 dwellings (highest) to post-1980 dwellings (lowest excess). This trend was steeper after correction for age, gender and socioeconomic group.

Dampness, which reflects both the condition of the building fabric as well as heating and ventilation, showed an unclear association with winter death. The excess in dwellings without central heating was small (4%) and statistically insignificant. A clearer gradient was seen with the Standard Assessment Procedure (SAP) energy rating, with homes with below average thermal efficiency having the highest risk.

Apart from property age, the strongest association was seen with low indoor temperature, there being a 20% difference in excess winter death between coldest and warmest houses. This difference was little affected by adjustment for socioeconomic group, presence of central heating and/or age of property.

Figure 4: Selection of study sample

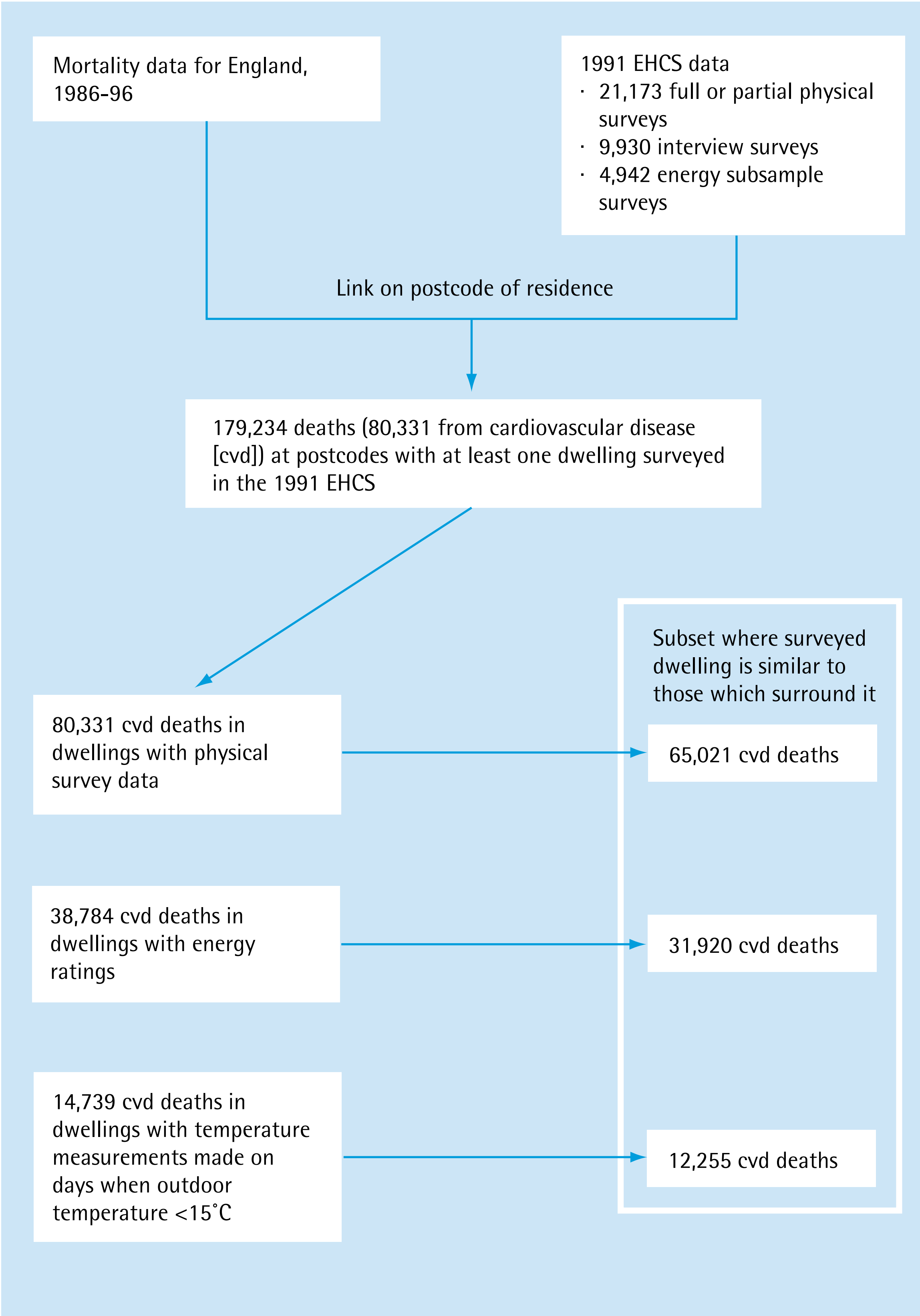


Table 1: Percentage excess winter death by personal and housing characteristics

	Winter deaths	% excess in winter	Risk (95% confidence interval) relative to baseline group	P-value for trend*
Age-group (*n*=80,331)[†]				
0-44	385	1.3	1.0	
45-64	4,008	18.9	1.17 (1.03-1.34)	
65-74	16,619	21.0	1.20 (1.05-1.36)	<0.001
75-84	23,204	22.6	1.21 (1.07-1.46)	
85+	14,169	30.0	1.28 (1.13-1.46)	
Gender (*n*=80,331)				
Male	15,000	21.3	1.0	
Female	15,467	24.5	1.03 (1.02-1.05)	0.09
Housing region (*n*=80,331)				
Range across the nine housing regions	2,407-5,346	17.9-27.4	10% variation	0.06*
Socioeconomic group, head of household (*n*=37,700)				
Professional	580	31.3	1.0	
Managerial	2,251	25.5	0.96 (0.85-1.07)	
Intermediate non-manual	1,197	21.8	0.93 (0.82-1.05)	
Junior non-manual	1,447	25.1	0.95 (0.84-1.08)	>0.2
Skilled manual	4,831	22.6	0.93 (0.84-1.04)	
Semi-skilled manual	2,803	23.3	0.94 (0.84-1.05)	
Unskilled manual	1,283	21.3	0.92 (0.82-1.05)	
Tenure (*n*=77,643)				
Housing association	2,540	18.6	1.0	
Local authority	10,601	20.5	1.02 (0.96-1.08)	0.008
Owner-occupied	14,242	25.2	1.06 (1.00-1.12)	
Private rented	2,067	25.8	1.06 (0.98-1.14)	
Property age (*n*=80,331)				
Pre-1850	701	28.2	1.0	
1850-99	5,469	25.6	0.98 (0.88-1.09)	
1900-18	3,063	24.1	0.97 (0.87-1.08)	
1919-44	6,978	26.0	0.98 (0.89-1.09)	0.001
1945-64	6,709	23.9	0.97 (0.87-1.07)	
1965-80	6,612	17.1	0.91 (0.82-1.01)	
Post-1980	935	15.0	0.90 (0.79-1.02)	
Condition: dampness (*n*=58,284)				
Satisfactory	18,189	22.2	1.0	
Acceptable	2,534	30.7	1.07 (1.01-1.13)	0.03
Defective	1,104	28.8	1.05 (0.98-1.13)	
Seriously defective	344	26.5	1.04 (0.91-1.18)	
Central heating (*n*=38,856)				
Yes	11,529	22.5	1.0 0.14	
No	3,250	27.3	1.04 (0.99-1.09)	

Table 1: Percentage excess winter death by personal and housing characteristics (cont)

SAP rating (*n*=38,785)					
Quartile 1: 51+ (most efficient)	3,511	19.4	1.0		
Quartile 2: 41-50	3,965	22.4	1.03	(0.97-1.09)	0.05
Quartile 3: 32-40	3,666	26.8	1.06	(1.00-1.13)	
Quartile 4: ≤31 (least efficient)	3,607	25.4	1.05	(0.99-1.11)	
Indoor temperature (*n*=14,739)					
Quartile 1 (warmest)	1,498	13.4	1.0		
Quartile 2	1,357	26.5	1.11	(1.02-1.22)	0.002
Quartile 3	1,247	17.5	1.04	(0.94-1.14)	
Quartile 4 (coolest)	1,488	36.3	1.20	(1.09-1.32)	

* The *p*-values (see glossary) test for a trend of increasing or decreasing risk across ordered groups (for example, increasing age). However, in the case of region, there is no logical order and the *p*-value tests whether the winter excess varies between regions.

† The *n* vary because different variables were recorded in different subsamples of the EHCS.

Table 2: Risk (95% confidence interval) of excess winter death relative to that of residents living in properties constructed before 1850

	Unadjusted (*n*=80,331)*		Adjusted for age and gender (*n*=80,330)		Adjusted for age, gender, socioeconomic group and central heating (*n*=37,654)		Adjusted for age, gender, socioeconomic group and index of indoor temperature (*n*=14,301)	
Pre-1850	1.00		1.00		1.00		1.00	
1850-99	0.98	(0.88-1.09)	0.99	(0.89-1.10)	0.97	(0.83-1.12)	1.04	(0.68-1.59)
1900-18	0.97	(0.87-1.08)	0.97	(0.87-1.09)	0.93	(0.80-1.09)	0.95	(0.61-1.46)
1919-44	0.98	(0.89-1.09)	0.99	(0.89-1.10)	0.96	(0.83-1.11)	1.05	(0.69-1.59)
1945-64	0.97	(0.87-1.07)	0.98	(0.88-1.09)	0.96	(0.83-1.11)	1.08	(0.71-1.64)
1965-80	0.91	(0.82-1.01)	0.92	(0.83-1.02)	0.87	(0.75-1.01)	1.01	(0.66-1.54)
Post-1980	0.90	(0.79-1.02)	0.90	(0.79-1.03)	0.82	(0.68-0.98)	0.89	(0.55-1.44)
P-value for trend	0.001		0.002		0.001		>0.1	

* The *n* vary because different variables were recorded in different subsamples of the EHCS.

Table 3: Age and gender adjusted risk (95% confidence interval, relative to pre-1850 dwelling) of excess winter death by cause

Age of property	Cardiovascular disease (*n*=80,382)		Respiratory disease (*n*=22,156)		Other causes (*n*=74,638)	
Pre-1850	1.00		1.00		1.00	
1850-99	0.99	(0.89-1.10)	0.82	(0.67-1.02)	1.08	(0.97-1.19)
1900-18	0.97	(0.87-1.09)	0.80	(0.64-1.00)	1.02	(0.92-1.14)
1919-44	0.99	(0.89-1.10)	0.86	(0.70-1.06)	1.04	(0.94-1.15)
1945-64	0.98	(0.88-1.09)	0.89	(0.72-1.10)	1.01	(0.91-1.12)
1965-80	0.92	(0.83-1.02)	0.82	(0.66-1.01)	1.00	(0.90-1.11)
Post-1980	0.90	(0.79-1.03)	0.89	(0.69-1.13)	0.98	(0.86-1.13)
P-value for trend	0.002		>0.2		0.003	

Table 2 shows the effect of adjusting for confounding factors on the association between excess winter death and age of property. The general trend of lower risk in more recently built houses was, if anything, slightly strengthened by adjustment for the presence of central heating and socioeconomic group, but flattened by adjustment for the index of indoor temperature, although the estimates in this case were based on a substantially smaller sample.

Table 3 shows that the association between excess winter death on the one hand and indoor temperature and age of property on the other was fairly specific for cardiovascular disease. For respiratory disease (a comparatively small sample) there was no clear trend with age of property, although pre-1850 dwellings had the highest risk. Non-cardiorespiratory deaths showed some evidence of a correlation with age of property.

Determinants of indoor temperature

Indoor temperature is perhaps the most immediate marker of exposure to cold. As the overall purpose of our study was to determine the extent to which coldness of the home increases the risk of winter death, an important intermediate goal was to identify the factors that determine low indoor temperature.

The tabulations below show hall temperatures 'corrected' to standard conditions of measurement: the indoor temperature at 3pm, after four hours of central heating, and an outdoor temperature of 5°C. Such correction was necessary because the EHCS temperature measurements were made at varying times of day and on days of different outdoor temperature. (Details of the correction procedure are available from the authors.) Temperature measurements made when the outdoor temperature exceeded 15°C were excluded because on such days the indoor temperature would indicate little of the effectiveness and use of home heating.

The main results are summarised in Tables 4 and 5. These show that there was little variation in corrected temperatures by age of the head of household, but that there was a weak trend for larger households to have slightly warmer homes. There was a clear gradient of decline in temperature from city to rural locations, and from higher to lower socioeconomic groups. There was also significant variation by housing tenure, with the highest corrected temperatures being found in housing association dwellings, and the lowest in privately rented accommodation. Average temperatures also increased with income and were lower in households receiving state benefits.

Results for dwelling characteristics are shown in Table 5. Dwellings built before 1900 were, on average, two degrees Celsius cooler than dwellings constructed since 1980. Indeed, there was a monotonic increase in mean corrected temperature with more recent date of construction, presumably reflecting improvements in building materials and design, and the introduction of building regulations with thermal standards.

Dwellings without central heating were two degrees Celsius cooler than dwellings that had central heating. Satisfaction with heating also appeared to be a good marker of indoor temperature – those householders who were very unsatisfied with it having an indoor temperature some 2.5°C lower than householders who were very satisfied with their heating system. There was also a gradient of declining temperature with increasing standardised heating costs, and with poorer energy efficiency ratings (SAP scores). Based on our corrected temperatures, it appears that around a third of all dwellings would fail to maintain a hall temperature of greater than 16°C when the outside temperature falls to 5°C. Even in dwellings constructed after 1980, which, in general, are the most energy efficient, nearly a fifth of households would have an indoor temperature below 16°C under these conditions.

Table 4: Indoor temperatures by household characteristics

	Number of dwellings	Mean measured temperature (°C)	Temperature corrected to standard conditions*	% of households with hall temperature <16°C at standard conditions*
Age of head of household				
16-39	922	17.9	17.1	31.9
40-59	1,095	17.9	17.2	30.3
60-74	834	17.7	17.1	33.8
75+	486	17.9	17.2	35.6
Household size				
1	811	17.6	17.0	38.6
2	1,130	17.9	17.2	30.9
3-4	1,115	18.0	17.2	30.4
5+	311	18.0	17.2	28.9
Location				
City centre	140	18.4	17.6	31.4
Urban	1,1016	17.9	17.2	31.5
Suburb	1,617	17.9	17.2	32.0
Rural residential	404	17.8	17.1	33.2
Village/rural	220	17.2	16.6	39.1
Socioeconomic group				
Professional	167	18.0	17.4	24.0
Employers and managers	531	18.4	17.6	24.1
Intermediate non-manual	323	18.2	17.4	27.9
Junior non-manual	321	17.7	17.1	33.3
Skilled manual	1,128	17.7	17.0	34.4
Semi-skilled manual	593	17.6	17.0	37.4
Unskilled manual	237	17.4	16.8	41.4
Housing tenure				
Housing association	253	18.4	17.7	28.9
Local authority	1,040	17.8	17.1	34.0
Owner-occupied	1,886	17.9	17.2	30.6
Privately rented	228	17.2	16.4	43.4
Net household income				
Quartile 1 (lowest)	856	17.5	16.9	37.3
Quartile 2	865	17.6	16.9	37.2
Quartile 3	843	17.9	17.1	31.9
Quartile 4 (highest)	843	18.4	17.6	22.9
75%+ of income from benefits				
No	1,882	18.1	17.3	29.4
Yes	1,152	17.6	16.9	37.4

* Standard conditions: at 3pm, after four hours of central heating, with 5°C outside temperature.

Table 5: Indoor temperature by dwelling characteristics

	Number of dwellings	Mean measured temperature (°C)	Temperature under standard conditions*	% of households with hall temperature <16°C at standard conditions*
Age of property				
Pre-1900	660	17.3	16.7	38.8
1900-44	1,157	17.5	16.8	36.0
1945-64	853	17.6	17.0	35.8
1965-80	621	19.1	18.4	17.6
Post-1980	116	19.5	18.7	14.7
Central heating				
Yes	2,639	18.3	17.6	25.0
No	766	16.3	15.6	57.6
Satisfaction with heating				
Very satisfied	1,600	18.5	17.8	23.0
Fairly satisfied	1,286	17.6	16.9	35.7
Fairly unsatisfied	303	16.8	16.1	44.2
Very unsatisfied	215	16.0	15.3	65.1
Minimum standard heating costs				
Quartile 1 (lowest)	826	19.0	18.2	20.6
Quartile 2	840	17.9	17.2	30.7
Quartile 3	859	17.6	16.9	35.6
Quartile 4 (highest)	865	17.0	16.3	41.8
SAP rating				
Quartile 1 (most efficient)	873	18.8	18.1	18.9
Quartile 2	875	18.1	17.3	30.7
Quartile 3	812	17.7	17.0	35.0
Quartile 4 (least efficient)	830	16.8	16.2	45.5

* Standard conditions: at 3pm, after four hours of central heating, with 5°C outside temperature.

Table 6 shows the results of analyses carried out to determine which of the housing and household characteristics were independent predictors of indoor temperature. The subset of seven variables that were found to be predictive were:

- *Household size:* larger families had warmer homes, single-person households cooler homes.
- *Net household income:* households with higher incomes had slightly warmer homes.
- *Geographical region:* the coolest homes were in the West Midlands, the warmest in London.
- *Age of the property:* newer properties were warmer.
- *Presence of central heating.*
- *Satisfaction with the heating system.*
- *Cost of heating the dwelling to a minimum standard:* which had an inverse relationship.

With these variables already included, housing tenure, having more than 75% of household income from state benefits, and SAP rating did not make significant additional contributions to the statistical model, although all three were individually associated with indoor temperature (as shown in Tables 4 and 5).

Table 6: Multivariable predictors of indoor temperature*

	Increase in hall temperature (°C) relative to baseline group	95% confidence interval	P-value
Household size			
1	0		
2	0.26	0.01 to 0.52	0.002
3-4	0.48	0.22 to 0.74	
5+	0.53	0.18 to 0.89	
Net household income			
Quartile 1 (lowest)	0		
Quartile 2	−0.08	−0.33 to 0.17	0.06
Quartile 3	0.07	−0.20 to 0.33	
Quartile 4 (highest)	0.25	−0.03 to 0.54	
Region			
1 Northern	0		
2 Yorkshire/Humberside	0.56	0.21 to 0.90	
3 North West	0.47	0.14 to 0.80	
4 East Midlands	1.01	0.65 to 1.37	<0.0001
5 West Midlands	−0.24	−0.58 to 0.11	
6 South West	0.36	−0.01 to 0.74	
7 Eastern	0.90	0.53 to 1.26	
8 Greater London	1.33	1.00 to 1.67	
9 South East	0.88	0.50 to 1.26	
Age of building			
Pre-1900	0		
1900-44	−0.06	−0.30 to 0.18	
1945-64	0.15	−0.11 to 0.40	<0.0001
1965-80	1.08	0.79 to 1.36	
Post-1980	1.20	0.70 to 1.71	
Central heating			
Yes	0		
No	−1.13	−1.35 to −0.90	<0.0001
Satisfaction with heating			
Very satisfied	0		
Fairly satisfied	−0.64	−0.82 to −0.46	<0.0001
Fairly unsatisfied	−1.13	−1.44 to −0.82	
Very unsatisfied	−1.81	−2.17 to −1.44	
Minimum standard heating costs			
Quartile 1 (lowest)	0		
Quartile 2	−0.57	−0.81 to −0.32	<0.0001
Quartile 3	−0.72	−0.97 to −0.46	
Quartile 4 (highest)	−1.10	−1.36 to −0.84	
Constant			
Temperature for dwellings in baseline groups	18.4	17.9 to 18.8	<0.0001

* Standard conditions: at 3pm, after four hours of central heating, with an outdoor temperature of 5°C.

Table 7: Mean corrected temperatures at standard conditions* (number of surveyed dwellings in parentheses)

	Standardised heating costs							
	Quartile 1 (lowest)		Quartile 2		Quartile 3		Quartile 4 (highest)	
Net household income								
Quartile 1 (lowest)	18.4	(n=294)	16.8	(*n*=207)	16.0	(*n*=183)	15.5	(*n*=165)
Quartile 2	18.3	(*n*=217)	17.1	(*n*=241)	16.6	(*n*=220)	15.5	(*n*=185)
Quartile 3	17.9	(*n*=173)	17.2	(*n*=203)	17.2	(*n*=237)	16.4	(*n*=225)
Quartile 4 (highest)	18.2	(*n*=142)	17.9	(*n*=189)	17.6	(*n*=219)	17.3	(*n*=290)
Housing tenure								
Housing association	19.0	(*n*=128)	16.9	(*n*=57)	16.4	(*n*=40)	14.6	(*n*=28)
Local authority	18.3	(*n*=386)	17.1	(*n*=288)	16.4	(*n*=224)	15.3	(*n*=140)
Owner-occupier	17.8	(*n*=276)	17.4	(*n*=450)	17.2	(*n*=542)	16.7	(*n*=608)
Privately rented	17.8	(*n*=36)	17.1	(*n*=45)	15.9	(*n*=53)	15.9	(*n*=89)

* Standard conditions: at 3pm, after four hours of central heating, with an outdoor temperature of 5°C.

Further cross-tabulations showed that the variation in indoor temperatures was, in fact, more complex than the simple tabulations suggest. Table 7 shows corrected temperatures by household income, housing tenure and standardised heating costs. In dwellings of low heating cost, the variation in temperature by housing tenure was relatively modest. In fact, housing association dwellings were warmest and privately rented the coldest. However, households living in housing association or local authority accommodation showed the largest fall in indoor temperature as heating costs increased, falling to 14.6° and 15.3°C respectively in the highest heating cost group. Fortunately, a relatively small proportion of households in these sectors had high heating costs, so the average indoor temperatures were comparatively high. This contrasts with the situation of owner-occupiers and privately renting households, which had comparatively low corrected temperatures when the heating costs were low, but maintained reasonable indoor temperatures even when the heating costs were high.

Thus, it appears that housing association and local authority dwellings are, on the whole, fairly easy to heat, but when heating costs rise, these households are often unable to meet the cost. In such cases, indoor temperatures may fall very low indeed, thus placing vulnerable individuals at appreciable risk. Owner-occupiers and households in privately rented accommodation are generally more able to afford even high heating costs, so indoor temperatures do not fall so far even when heating costs are high. A similar pattern was observed from classifying households by income rather than tenure (Table 7). Again, in dwellings with low heating costs, temperatures were well maintained at relatively good temperatures whatever the household income. But, as heating costs increased, the fall in temperatures was substantially sharper in households on a low income.

Time-series analysis: the association between daily mortality and outside temperature

The third phase of analysis focused on the association between daily mortality and outdoor temperature. The thrust here was to obtain evidence relating to the specific hazard of low temperatures, and whether the association between low outdoor temperature and mortality was stronger in those living in cold homes compared with those living in warm homes. Cold and warm homes were defined by:

1. measured hall temperatures corrected to standard conditions;
2. predicted hall temperatures – the predictions being made from dwelling characteristics and the socioeconomic circumstances of the inhabitants.

Figure 5: Schema of time-series data linkage and analysis

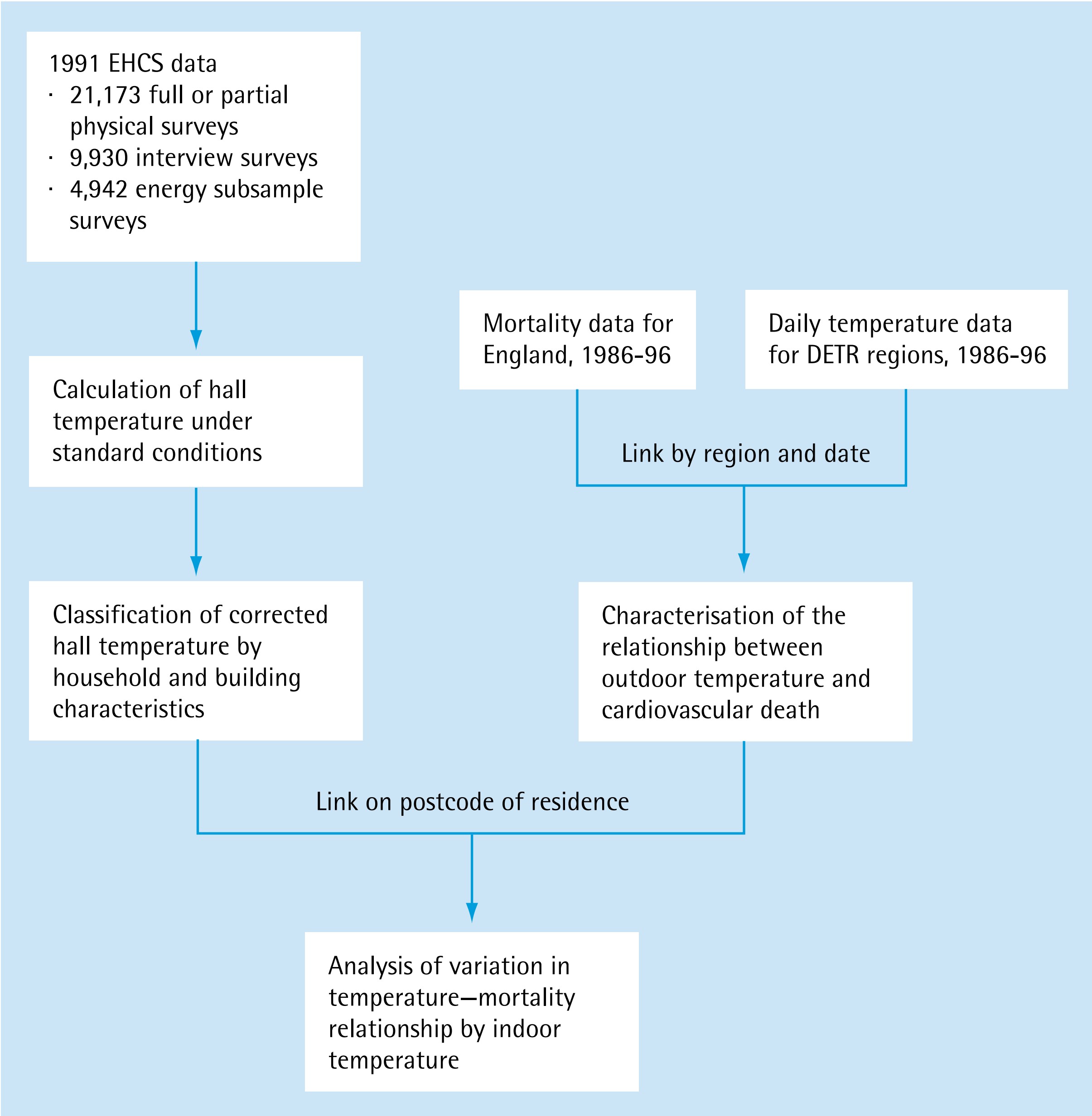


Figure 6: Seasonal fluctuation in mortality in cold and warm homes

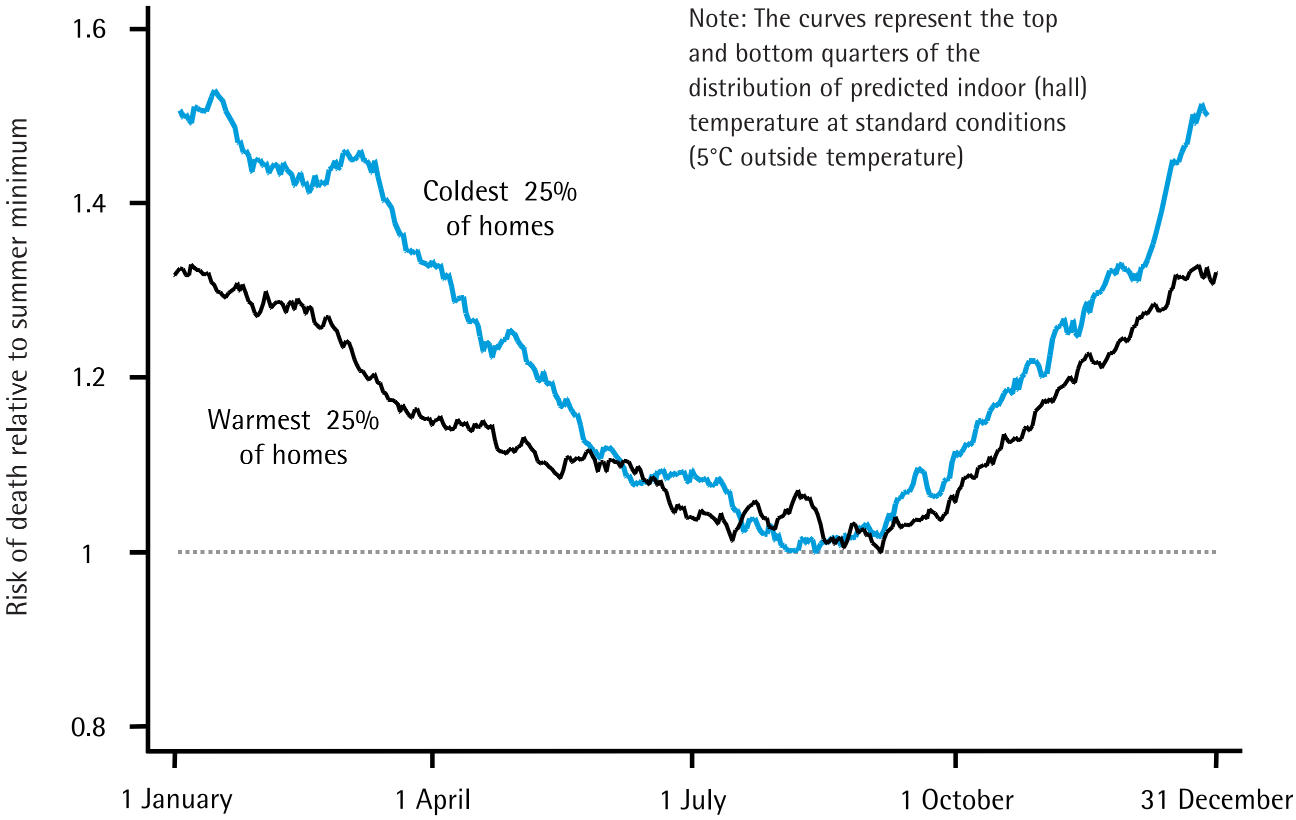
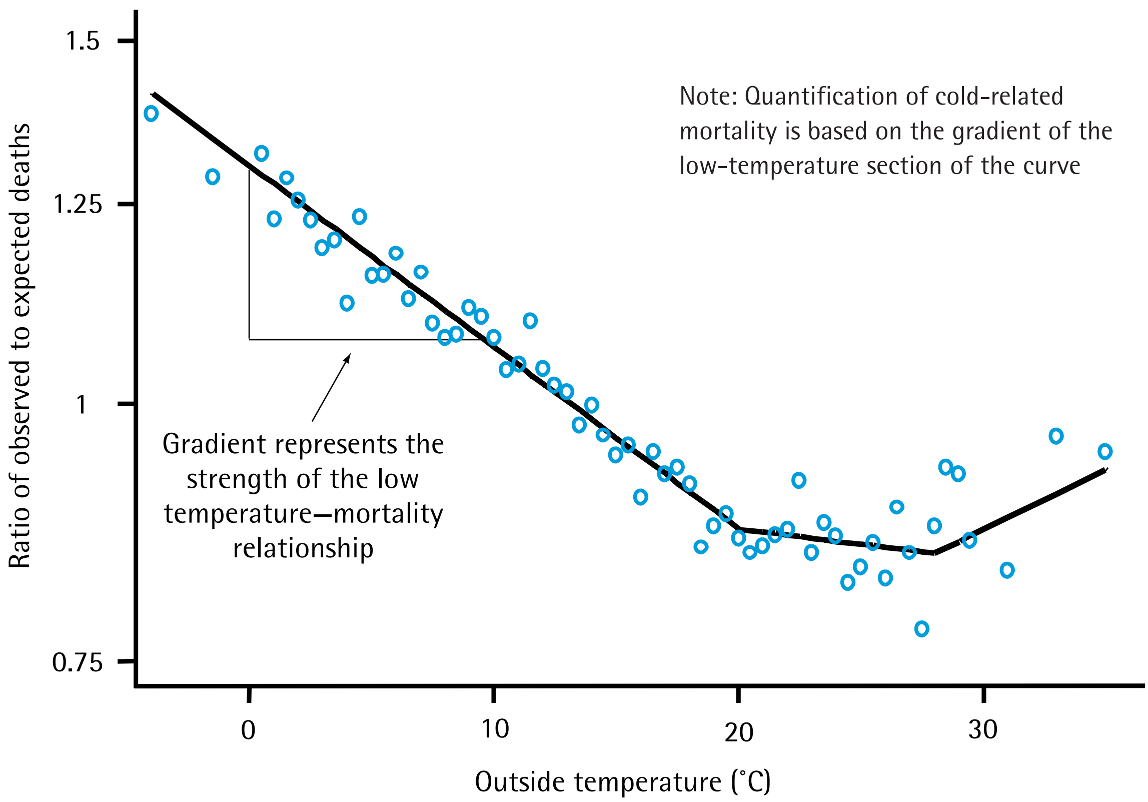


Figure 7: Temperature mortality relationship as a three-piece function



Although corrected hall temperatures provide the most direct indication of the adequacy of home heating usable measurements were available for only 16% of homes in the 1991 EHCS. However, the analyses described in the previous section made it possible to calculate predicted indoor temperatures for a much larger proportion (47%) of homes using six variables: household size, household net income, region, building age, presence of central heating and standardised heating costs.

The methods of time-series analysis were a modification of those that have been widely used to study the relationship between outdoor air pollution and adverse health effects (Schwartz et al, 1996). The objective was to quantify the association between daily temperature and mortality by linking mortality, temperature measurements and EHCS data as shown in Figure 5.

Figure 6 shows the seasonal pattern of cardiovascular deaths using data for the years 1986-96 collapsed into one artificial year of 365 days. This graph thus groups together deaths on the same day of each year across the whole of this period. The *y*-axis represents the relative increase in death compared to the lowest death rate at the summer trough.

The curve, which has been statistically 'smoothed' to bring out the underlying seasonal pattern, shows the substantial variation in risk across the seasons, with the highest death rate in winter being some 1.4 times that of the minimum death rate of summer. Pertinent to the current analyses is the observation that the amplitude of seasonal fluctuation is much larger in people living in the coldest homes (the bottom 25% of the predicted hall temperatures) than it is for people living in the warmest homes (the top 25% of the predicted hall temperatures). Even without more formal analysis, this suggests that people living in cold homes are more vulnerable to winter death. It seems likely that this is directly related to the temperature conditions of their living environment.

Figure 7 shows the relative risk of death as a function of daily temperature. Mortality rises at temperatures below 20°C, is fairly constant between 20°C and 28°C, and rises at temperatures above 28°C. This three-piece function reflects the fact that deaths rise from exposure to cold and also from the physiological stress of heat. Between these two extremes (20-28°C maximum daily temperature) the ambient conditions are physiologically comfortable, and there is no clear relationship with death rates, which are at their minimum.

From a housing perspective, the primary interest was to quantify the degree to which the 'cold slope' varied with the intrinsic 'coldness' of dwellings. Further mathematical modelling showed that the relationship between outdoor temperature and mortality was steeper among residents of intrinsically cold homes than among those living in warmer homers. In other words, for each degree Celsius fall in outdoor temperature, the percentage rise in mortality is greater in those living in cold homes (the rise was about 2.8% per degree Celsius in the coldest 10% of homes and 0.9% in the warmest 10% of homes).

3

Discussion and policy implications

This study provides, for the first time, direct evidence that poor housing quality in Britain may be linked to the large winter excess of deaths from cardiovascular and other diseases.

The study's major strength comes from the linkage of mortality statistics to data on housing conditions from a large national survey – the 1991 EHCS – which covered more than 21,000 dwellings across England. This linkage had two main advantages. First, it made it possible to examine mortality specifically in relation to the heating characteristics and indoor temperatures of homes; second, it yielded a large sample size so that risks could be estimated with adequate precision.

In the section that follows, four issues arising from the results of our study are considered:

1. the strength of evidence for a causal link between cold homes and winter mortality;
2. what the study tells us about vulnerable groups;
3. the implications for potential public health benefits from initiatives to improve the thermal efficiency of homes;
4. questions for further research and policy development.

Strength of evidence

If asked to summarise the evidence of this study in one sentence, it would be this:

the findings provide strong, although not conclusive, evidence that winter mortality and cold-related mortality are linked to sub-optimal home heating.

These findings are consistent with other published evidence on the health effects of low ambient temperatures.

The evidence has three parts. First, the study showed that the substantial winter–summer difference in mortality is greater in dwellings and households whose characteristics are associated with poor home heating – factors such as age of property, high standardised heating costs and low income. Low indoor temperature itself was found to be an important predictor of excess winter mortality.

Second, it showed the substantial variation in indoor temperatures and the particularly low indoor temperatures during periods of cold weather in households that have both high standardised heating costs and low income.

Third, it showed that the indoor temperatures predicted from household and dwelling characteristics appear to determine the seasonal pattern of mortality and, specifically, the strength of association between low outdoor temperatures and cardiovascular death. Residents of dwellings that are intrinsically cold (that is, predicted to have low indoor temperatures under standardised conditions of low outdoor temperature) were found to have a substantially larger seasonal swing in death rates than residents of warmer homes and a greater percentage rise in death rate for each degree Celsius fall in outdoor temperature.

Thus, the results indicated not only that older, less thermally efficient and intrinsically colder houses were associated with a greater seasonal excess of mortality, but also that such houses were specifically associated with vulnerability to cold-related mortality.

The evidence of a causal association is strengthened by the fact that the housing factors associated with winter death were factors associated with cold indoor temperatures. Poor energy efficiency rating (SAP score), high standard heating costs, absence of central heating and property age are all proxy markers of low indoor temperature. With property age, for example, the thermal efficiency of dwellings and their insulation against the cold has improved over time as building methods and technology have advanced; since 1964, building regulations have required progressively higher insulation standards of new housing stock. It may be significant that the greatest reduction in excess winter death in relation to building age occurred around 1965 – the time when thermal efficiency first became part of building regulations.

Evidence for a causal link is also strengthened by the fact that the associations between building characteristics and mortality were greatest for cardiovascular disease. The lack of clear association for respiratory disease is surprising, although confidence intervals were much wider for respiratory disease because of the much smaller sample size. What the findings may signal is that the winter rise in respiratory death is more to do with respiratory infection and other seasonal changes than it is to do with the direct effects temperature per se (although, of course, temperature may indirectly be a factor in the spread of infectious illnesses). A cold effect on cardiovascular death is biologically and socially plausible, and there is evidence of the potential mechanisms of temperature stress (Wilmshurst, 1994; Khaw, 1995) operating on the circulation, blood coagulation and thrombosis (Keatinge et al, 1984; Woodhouse et al, 1993; Neild et al, 1994; Stout et al, 1996).

One concern that has been raised about the study design is the fact that it relied on linking mortality and housing data on the basis of postcodes of residence (there are around 14 dwellings per postcode) rather than individual homes. It therefore entailed an assumption that the surveyed property is representative of those which surround it. While clearly untrue for every dwelling, this seems a reasonable assumption when drawing inferences of association averaged across a very large sample. There is, after all, no reason to believe that surveyed properties had a systematically higher or lower temperature than other dwellings at the same postcode. Hence, if there is misclassification, it is likely to be random. Such misclassification tends to weaken associations rather than produce spuriously positive ones. Moreover, the EHCS included an indicator of whether a dwelling is similar to properties that surround it, and restriction of analysis to the subset of dwellings where the dwelling was considered representative made no material difference to the results. Our conclusion on this point is, therefore, that if there is a bias, it is most likely to be conservative.

Another issue is whether residents in older, colder homes are at greater risk of winter- or cold-related death for reasons that are unrelated to home heating. The most plausible possibility is that those who live in cold homes are also of low socioeconomic status and that it is some other aspect of their poverty, such as poor nutrition, that gives them high risk of winter death, rather than indoor temperature. This possibility cannot be discounted, but the fact that the observed association appears specific for temperature-related factors and cardiovascular disease challenges this to some degree. It is also worth remembering that the temperature association is both biologically plausible and consistent with other published evidence on the health effects of low temperature. Moreover, it is worth noting that we found that low socioeconomic group was not strongly related to winter death unless looked at in combination with the cost of home heating.

Even if poverty is the main factor, the cost of home heating is likely to have an important influence on the income households have to spend on food and other items, so it may still be a significant, although indirect, determinant of mortality. In other words, high heating costs may have adverse consequences to health through more than one channel.

Overall, the conclusion remains that the most probable explanation for the observed associations is the direct effect of low indoor temperature, which is a function of the thermal efficiency of a dwelling and household income.

Vulnerable groups

In terms of individual vulnerability, the results confirm that it is older people who are at greatest risk of excess winter death. Although slight winter excess is seen at all ages, the magnitude of the excess rises very steeply with age. As absolute death rates are also obviously higher in older age groups, it is clear that those aged over 65 are by far the most significant group in terms of the number of excess winter deaths. These should therefore be a key target group for public health interventions.

What was unexpected in the results was the flatness of the relationship between excess winter death and socioeconomic group. In fact, without adjustment for other factors, the gradient inclines towards a higher risk in the professional and managerial grades and a lower risk in unskilled and semi-skilled workers. This seems counter-intuitive and at odds with notions of fuel poverty as a factor in winter death.

However, as the analyses of indoor temperature show, the interrelationships between poverty, home temperature and mortality are complex. Two observations are worth making here. First, although lower socioeconomic groups have high absolute rates of cardiovascular disease it is not obvious that they should also have a high relative increase in cardiovascular death in winter. Second, temperature measurements suggest that lower socioeconomic groups do not have substantially cooler homes than higher socioeconomic groups. This may in part be behavioural, but it also appears that temperatures in housing association and local authority dwellings are higher than in owner-occupied and privately rented dwellings. This may relate to the year of construction of the homes and to efforts by local authorities to ensure adequate heating in social housing stock.

Moreover, the analyses of indoor temperatures show that there are some households in local authority and housing association dwellings, which do have very low indoor temperatures. These are most likely to occur when the heating costs are high. Thus, residents in housing association and local authority stock mostly live in recently built and thermally efficient accommodation and are able to maintain comparatively high indoor temperatures. However, the small proportion who live in stock which is costly to heat, are not able to do so. In contrast, as a group, owner-occupiers maintain comparatively cool indoor temperatures, but those temperatures do not fall substantially even when heating costs are high.

Clearly, the risks of excess winter death are quite widely distributed across social groups and types of housing; concentration only on one housing sector or solely on the highest risk groups would therefore have limited impact on excess winter deaths as a whole. If we accept the evidence of this study that it is low indoor temperature that is of primary importance from a housing point of view, the combination of housing characteristics and household income provide a reasonable basis for identifying households at greatest risk. However, consideration must also be given to the improvement of indoor temperatures in other dwellings, which collectively account for a substantial part of preventable winter deaths. The fact that many of these households will have good incomes, implies a more complex strategy than simply providing grants to up-grade dwellings occupied by those on low incomes.

Potential public health benefits

The evidence of this report adds weight to arguments for improving the heating and energy efficiency of homes. The winter of 1991/92 was mild so the 1991 EHCS does not necessarily provide an accurate picture of how cold homes become when outside temperatures fall very low. Despite this, the survey showed that a large proportion of homes had measured indoor temperatures that failed to meet the standard heating regime (21°C in the living room and 18°C in other rooms) and, indeed, even the minimum regime as defined by DEFRA (18°C in the living room and 16°C in other rooms). This would, in any case, be a concern from a quality of life perspective, but the evidence of this study suggests that these low indoor temperatures also increase deaths and probably other adverse health events as well. Moreover, those with some of the least energy efficient and, hence, coldest homes include lone pensioners and other vulnerable groups.

The concept of 'affordable warmth' has been defined on the basis of the proportion of household income which must be spent to achieve a specified level of heating. The common definition of fuel poverty is when a household would need to spend more than 10% of its income on all fuel use to achieve the standard heating regime. Table 8, below, taken from a government report (DETR, 1999), shows that this definition applies to many homes.

Table 8: Number of households (thousands) in fuel poverty, England (1991 and 1996)

		Households needing to spend % income on fuel		
Year	**Number of households**	**<10%**	**10–19.9%**	**>20%**
1991	19,111	12,482 (65.3%)	4,360 (22.8%)	2,270 (11.9%)
1996 estimates	19,643	14,367 (73.2%)	4,092 (20.8%)	1,184 (6.0%)
1996 estimates*	19,643	15,271 (77.8%)	3,598 (18.3%)	774 (3.9%)

* Including housing costs in calculation of household income.
Source: Adapted from DETR (1999, p 11)

It is clear, then, that if the heating systems and energy efficiency of homes could be improved, substantial public health benefits should follow. To its credit, the government has taken these arguments seriously and is currently implementing a new Home Energy Efficiency Strategy (HEES) aimed at reducing the number of households in fuel poverty (DETR, 1999).

It is, however, difficult to estimate how large the benefits might be from home energy improvement measures. Only a proportion of winter deaths is attributable to low temperatures and we have, as yet, only broad quantification of the magnitude of the excess winter deaths that can be ascribed to inadequate home temperatures. The potential impacts of different forms of intervention and the most effective means of targeting are complex questions beyond the scope of this project, but a few general points are worth making.

It seems wise to concentrate effort on improving the energy efficiency of homes, rather than on giving additional payments to cover fuel bills. There may be a role for assistance with fuel bills for households in greatest need, but there are several advantages to improving energy efficiency as the first priority:

- it is a more lasting solution;
- it is easier to maintain indoor temperatures once such improvements have been made;
- such improvements favour overall reduction of energy use with wider environmental benefits.

In many cases it is estimated that the cost of implementing energy efficiency improvements could be recovered within a few years from reduced fuel costs, although, in practice, households tend to spend part of the efficiency gain on having a warmer home, rather than on lower fuel bills (which is appropriate from the point of view of gaining health benefits). However, the cost savings may not accrue to those who pay for the improvements.

There are, of course, limits to what can be achieved by implementing energy efficiency schemes, if only because of the physical characteristics of existing stock (especially older dwellings) and incomplete coverage. A particular problem is dealing with the very oldest existing stock without cavity walls and with rather poor insulation properties of the building fabric. On the other hand, there are no restrictions, other than financial ones, on the standards to which new homes can be built. There is a good case for strengthening building regulations and promoting much greater thermal efficiency of all new dwellings.

Cold-related death is not confined solely to high risk households. As our analyses show, the risk is in fact distributed across all social strata and all areas. Moreover, even if vulnerable groups are targeted, up-take may be patchy and the distribution of high-risk homes will change over time. We do not yet have the evidence to assess the costs and benefits of alternative strategies, but such work will be needed if we are to make the best use of limited resources.

No single measure will solve the burdens of ill-health due to inadequate home heating. Public health gains are likely to be greatest if a multifaceted strategy is employed and home energy efficiency is a key part of a wider energy policy. Perhaps the most important point is to recognise the true burden of winter-related mortality and morbidity and to take fuller account of it in all relevant areas of social policy.

The UK government's new HEES is likely to make an important contribution to improving public health. This scheme specifically targets energy efficiency improvement on the most vulnerable groups of owner-occupiers – the sector with the largest number of fuel poor households – and in private rented accommodation – the sector that includes the highest proportion of fuel poor households. The main thrust in relation to social housing is through an increase in the capital resources available to local authorities for housing. We should recognise, however, that the public health impact of these measures is likely to be modest in relation to the overall burden of winter death. Steps are now being taken to evaluate HEES, and this should provide us with a clearer picture of its benefits and costs. But other policy initiatives will be needed to tackle what will remain a major public health issue.

Further issues

The results of this research naturally raise many questions. From a practical standpoint, perhaps the most obvious question is, given the observed association between inadequate home heating and winter death, what reduction can a programme of energy efficiency measures achieve? The evidence is persuasive that there should be health benefits, but there are reasons why interventions might achieve less than the theoretical maximum. It will therefore be important to verify that improvements in home energy efficiency do, in fact, translate into measurable reductions in the risks of winter- or cold-related death, and to quantify those benefits. It is welcome that government departments are now beginning to address this.

Alongside this it will also be important to consider what forms of housing, energy and social policy are likely to deliver the greatest public health benefits, and at what cost. This is a complex question but one that should be amenable to systematic analysis. The complexity lies in the variety of possible policy options, the distribution of risks in different social groups, the heterogeneity of the housing stock, issues of targeting and uptake, the range of outcomes and issues of choice. The question also impinges on some core policy areas and thus merits wide debate. Through such debate it is to be hoped that strategies will be developed to maximise the public health gains.

4

Conclusions

Britain has a large winter excess of mortality, which is greater than in many other European countries. Although the reasons for our poor position are not clearly understood, much of the winter increase in mortality is attributable to the direct or indirect effects of cold, and there are strong theoretical reasons to think that inadequate home heating may be an important risk factor.

This research aimed to investigate this, using both seasonal and daily time-series analyses. The results provide evidence that the substantial winter–summer difference in mortality is indeed related to indoor temperature and to dwelling characteristics that are determinants of indoor temperature. Moreover, indoor temperatures predicted from household and dwelling characteristics appear to influence the seasonal pattern of mortality and, more specifically, the strength of association between low outdoor temperatures and cardiovascular death. People living in dwellings that are intrinsically cold had a substantially larger seasonal swing in death rates and a greater percentage rise in mortality for each degree Celsius fall in outdoor temperature.

Although not conclusive, these findings suggest that indoor temperature and markers of the thermal efficiency of dwellings, including property age, are determinants of vulnerability to winter death from cardiovascular disease. This suggests that substantial public health benefits can be expected from measures that improve the thermal efficiency of homes and the affordability of heating them. Evaluations now underway of the government's HEES should provide evidence on this. However, wider debate is also needed to consider the forms of housing, energy and social policy that are likely to deliver the greatest public health benefits in relation to winter death.

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