EVIDENCE REVIEW & ECONOMIC ANALYSIS OF EXCESS WINTER DEATHS

Quantitative and qualitative evidence reviews for NICE guidance on excess winter deaths (EWDs): effective implementation and delivery of interventions and approaches for the prevention of EWDs and morbidity and the health risks associated with cold weather and cold homes

Full economic analysis for NICE guidance on excess winter deaths (EWDs): effective implementation and delivery of interventions and approaches for the prevention of EWDs and morbidity and the health risks associated with cold weather and cold homes

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Glossary

Excess winter death (EWD)	By convention established by Curwen (), the deaths per day in the four coldest 'winter' months (December, January, February, March for the northern hemisphere), minus the deaths per day over other ('non-winter') months, all divided by the average deaths per day over the non-winter months $$\frac{\frac{\sum_{deaths}[Dec, Jan, Feb, Mar]}{120} - \frac{\sum_{deaths}[Aug, Sep, Oct, Nov, Apr, May, Jun, Jul]}{245}}{\frac{\sum_{deaths}[Aug, Sep, Oct, Nov, Apr, May, Jun, Jul]}{245}}$$
Time-series study	

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1 Excess winter death and populations vulnerable to cold

Identification of at risk populations vulnerable to the consequences of cold temperatures and poorly heated or expensive to heat homes.

1.1 Seasonal variation in health and the role of cold temperatures **[Concept Piece 1]**

Populations in most temperate regions of the world experience appreciably higher rates of mortality and morbidity during winter months than at other times of the year, though the degree of such winter excess varies from setting to setting. The daily mortality pattern for London shows many of the typical features of seasonal and other temporal variation in mortality risk (Figure 1). These include:

- appreciable day-to-day fluctuation in mortality reflecting random variations and the effect of daily variation in specific time-varying risk factors, including air pollution and day of the week effects (mortality is generally highest on Mondays and lower at weekends than on weekdays)
- sharp 'spikes' in mortality, notably in January 2000, largely attributable to the influenza epidemic of that winter, and in July-August 2003, which is attributable to the exceptional summer heat wave of that year (renowned for its pronounced impact on mortality in Paris and other parts of continental western Europe)
- a fairly, but not absolutely, regular annual periodicity corresponding to the broad seasonal fluctuation in death rate, with deaths highest in winter (December, January, February) and lowest in summer (June, July August). To a reasonable approximation this fluctuation can be represented as a sinuisodal function, but there are clear departures from the regularity and shape of the sine function from year to year.
- an underlying downward trend in daily deaths that may reflect gradual trends in the size and characteristics of the London population and improvements in health and health care over time.

Compartmentalizing such continual variation in mortality into a winter excess is a matter of somewhat arbitrary definition. An alternative to a 'winter' definition is to quantify mortality excess not on the basis of seasonal timing but on the contribution of particular time-varying risk factors – most notably low temperature. In the UK, in years without an influenza epidemic, cold is the most important risk factor contributing to the seasonal fluctuation in mortality and hence to the 'winter excess'. It is worth noting that although the effect of heat on mortality is sometimes visible as a short peak in deaths (as in the summer of 2003), this is because heat deaths tend to occur on the same day or shortly after the day of heat. This is not so for cold, which typically results in a rise in deaths over a period of two or three weeks (as further described below). Its effect is therefore visible as a gradual seasonal rise ('swelling') in deaths in the winter months, and rarely if ever as one or more 'cold spikes'.

In theory almost every time-varying risk factor for death contributes to the seasonal fluctuation in mortality. However, some factors, such as changes in activity patterns across the year and seasonal changes in micronutrient levels are difficult to quantify, and are often assumed to be part of the residual seasonal fluctuation after the main risk factors are allowed for. In most circumstances the main risk factors contributing to seasonal fluctuation in deaths are low temperature and influenza.

Figure 2 indicates the month-to-month variation in death rates for a UK population showing the residual fluctuation that remains after adjusting for each of these factors individually and then both together. For this population the estimates were that cold was responsible for X percent of the month to month variation, influenza for Y percent and both combined for Z percent.

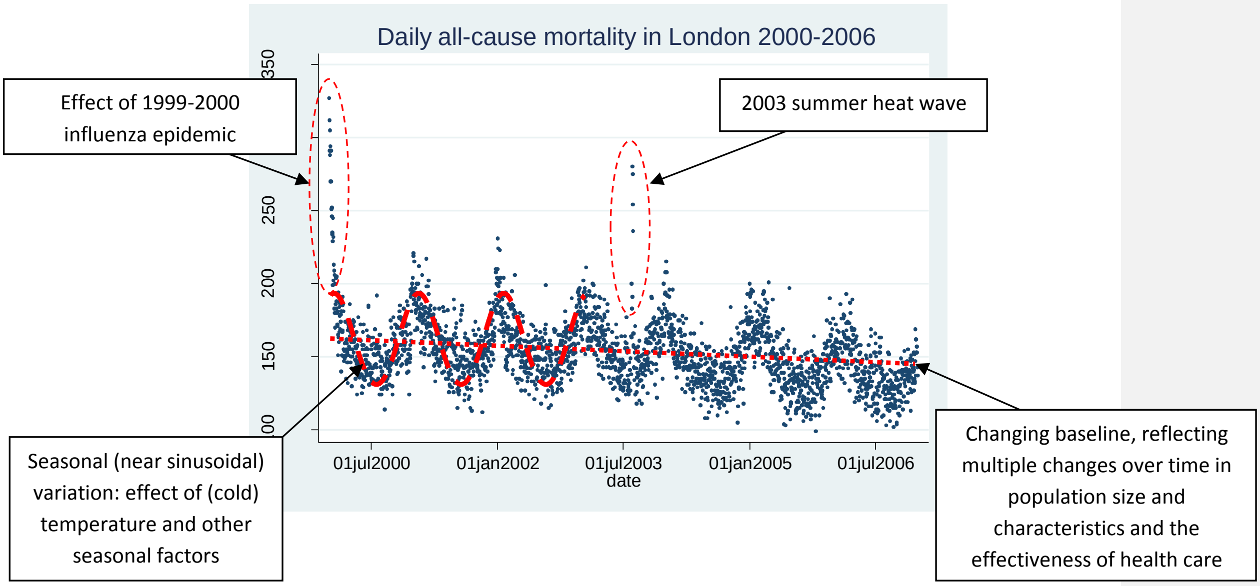

Figure 1. Daily number of all-cause deaths in London, 2000-2006

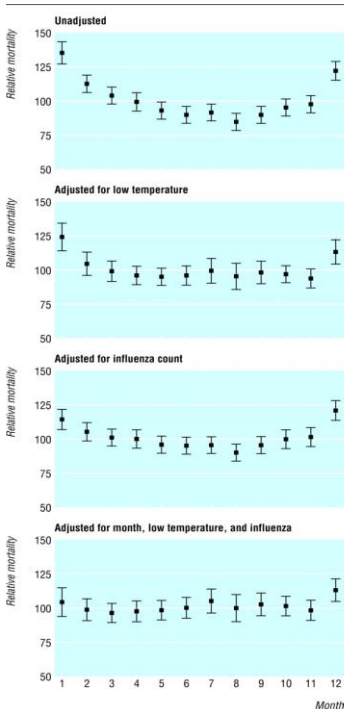

Figure 2 Monthly variation in deaths in the UK before and after adjustment for the effect of low temperature, influenza or both. Source: Wilkinson et al 2001.(1)

Comment [pw1]: Check. Is this for the cohort or a national population? Also the last figure is surely mislabelled: adjustment for influenza and cold only??

Definition of excess winter death

A common and simple way to quantify the wintertime risk is to measure the rate of health events (mortality etc) occurring during the winter season compared with that observed at other times of the year. The ratio of mortality between winter and non-winter months is an index, which takes a value of greater than 1 if there is a winter excess, and less than 1 if there is a winter 'deficit'.

This index of course depends on which months are defined as winter. The UK Met Office defines winter as the months of December, January and February, but the most common metric of excess winter death, proposed by Curwen,(2) assumes winter to comprise the *four* months of December to Month inclusive. Thus, his Excess Winter Mortality (EWM) Index, which is now widely used for statistical reporting in the UK, is the average deaths per day in the four coldest months (December, January, February, March for the northern hemisphere; June, July, August, September for the southern hemisphere), minus average deaths per day over the non-winter (warmer) months, all divided by the average deaths per day over the non-winter months.(2) The formula for the northern hemisphere is therefore:

$$\frac{\frac{\sum_{deaths}[Dec, Jan, Feb, Mar]}{120} - \frac{\sum_{deaths}[Aug, Sep, Oct, Nov, Apr, May, Jun, Jul]}{245}}{\frac{\sum_{deaths}[Aug, Sep, Oct, Nov, Apr, May, Jun, Jul]}{245}}$$

Alternatively, the annual distribution of deaths may be modelled as a sinusoidal or other cyclical curve, with the differences in deaths between one season and another measured as, for example, the difference between the top and the bottom of the curve, or alternatively the difference between the middle and top of the curve. Studies comparing excess winter mortality levels in different countries have found excesses ranging from around 8% in parts of Scandinavia and Russia, to around 20% in Australia and New Zealand.(3) In temperate Europe, the UK, Ireland and Portugal have a high winter excess.(4) Some advantages and disadvantages of the excess winter mortality index are highlighted in Box 1.

Box 1: Advantages and disadvantages of using an excess mortality index to determine wintertime burdens

Advantages:	**Disadvantages:**
• It is easy and quick to calculate without recourse to advanced statistical methods. • It is readily understood by the public and policymakers • It provides an index for comparison of winter burdens across years and between different countries.	• It is over simple: seasonal changes in health do not occur according to fixed calendar dates. • The ratio may be sensitive to the seasons used as the denominator, e.g. if summer months are included the occurrence of a heat-wave may inflate denominator deaths. • It doesn't allow for identification of which weather factors are important for health or for the specific conditions, e.g. are cold-spells occurring early in the winter worse than later ones? • Not all deaths due to cold occur during the winter, and not all of the winter excess is due to cold. • Comparison based on a 'seasonal index' between populations with different climatic patterns may be misleading

Since excess winter mortality indices may reflect high wintertime burdens due to circulating infections and other seasonal factors unrelated to weather, annual excess winter death statistics may not necessarily be highest in the winters with the most severe weather. For this reason, epidemiologic studies aiming to characterise the relationships between health and weather factors commonly use more sophisticated techniques which allow for quantification of the explicit contribution of weather factors separate from other seasonal components. It is this type of studies and their methods of attribution which is the basis for defining cold burdens, as further discussed below.

In summary

- There is an excess of deaths in winter in most countries with a temperate climate, which is usually quantified by calculating an excess winter mortality index.

- The UK has one of the highest excess winter mortality rates in Europe.

- Not all of this excess can be attributed to exposure to weather factors, thus limiting the potential for targeted health intervention measures.

1.2 Attribution of mortality and morbidity to cold **[Concept piece 2]**

Although excess winter mortality and morbidity indices allow for rapid assessment of the additional health impacts experienced during winter months compared to at other times of the year, they do not allow for attribution of the explicit contribution made by weather factors to this excess, as separate from other seasonal components. By contrast the best epidemiologic evidence on the effects of weather on health usually assess changes in the number of health events in relation to fluctuations in the weather, whilst controlling for other seasonal factors. These studies are usually based on conducting regression analysis of time-series data.

Time-series regression studies

These studies use data consisting of sequences of health events measured at regular intervals of time, for example the daily number of deaths over a period of a few years. As part of the analysis, any trends and broad seasonal patterns in the health data not driven by weather are adjusted for, as well as time-varying confounding factors such as circulating infections and sometimes air pollution concentrations. The most commonly characterised relationship is that between the daily number of deaths and daily ambient temperature measurements in any particular setting. Although other weather factors may also play a role,(5) the main health impacts are driven by temperature exposure. As these studies control for longer-term changes in the health data, they only allow for assessment of acute effects (i.e. a few days or weeks) of cold weather exposure. Potential chronic effects of cold exposure would not be detectable.

Very few of these impacts will be as a direct result of hypothermia,. The but mainly due to cardiovascular and respiratory problems. As cold is rarely indicated on a death certificate as a causal factor, its contribution is often unreported.]

The relationship between ambient temperature and health

After controlling for confounding in the manner described above, time-series regression studies then seek to assess the form of the relationship between temperature and health. Figure 2.1 shows the temperature-mortality relationship in London for temperatures throughout the year. Here, as in many populations, the risk of death rises in a smooth, roughly linear, fashion in relation to a fall in temperature below a cold threshold. The effects of cold are therefore commonly expressed as a percent change in deaths for every 1 degree decrease in temperature below the cold threshold. This risk is sometimes referred to as the cold slope, and both the value of the threshold and the steepness of the slope may vary across cities and countries depending on differing climatic, demographic and socio-economic profiles. Cold slopes have been estimated for each region of England and Wales,(6) as well as a number of settings globally.(7, 8) In many cases, the cold threshold becomes apparent at relatively moderate values of temperature, indicating that the adverse effects of cold exposure can occur at even moderate levels of temperature and are not restricted to extremes of winter weather. Although in the figure the heat slope is steeper that the cold slope, the cold effect becomes more dominant when delayed effects of temperature are also considered (see next section). Also, due to the greater number of days below the cold threshold than above the heat threshold, the burden from cold weather in the UK is currently substantially larger than that from hot weather.

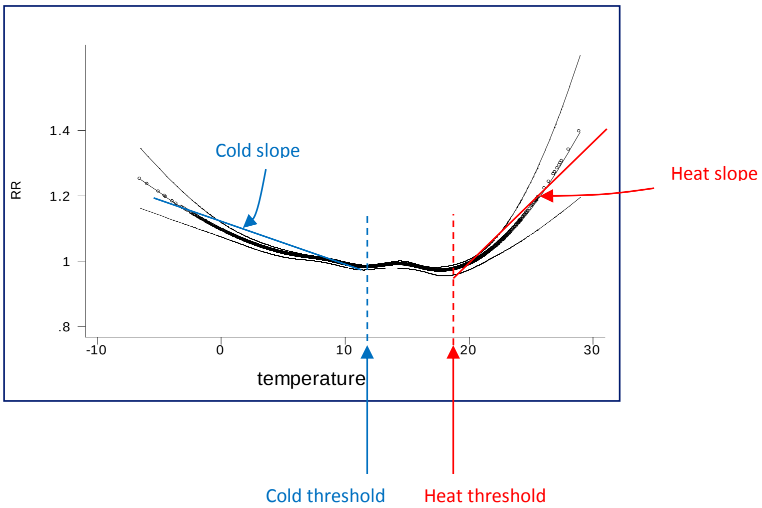

Figure 3. Relationship between the relative risk (RR) of all-cause mortality and mean temperature in London. Thick line is the estimated relationship based on spline functions; thin lines are 95% confidence limits.

Lagged effects of cold

One key consideration in the assessment of cold risk is that cold effects are generally delayed by several days or weeks following initial exposure. The effects of exposure may, therefore, be distributed across many subsequent days of mortality counts, creating a need in studies of this type to simultaneously model exposure effects over multiple days. Such a distributed lag curve is shown for various outcomes in 15 European cities combined in Figure 4.(7) It can be seen that the effect of cold on CVD deaths peaks a few days following exposure and then tapers to zero effect after about 3 weeks, whereas the respiratory deaths are longer sustained. For each outcome, summing the effects of the individual lags provides a total effect of short-term exposure to low temperatures.

In contrast to deaths related to summertime temperatures, there is little evidence that cold-related deaths are explained by a simple shortening of deaths by a matter of a few days or weeks in already frail individuals,(9) although potential life-shortening by months or years is not possible to detect in these type of studies.

Cold weather and morbidity outcomes

For both excess winter indices and cold threshold/slope estimates, the end-point most commonly analysed is mortality, but morbidity outcomes may also be sensitive to ambient temperature. Effects of low temperatures have been noted for emergency hospital admissions,(10) accident & emergency visits,(11) and GP consultations in the UK,(12) although in general risks are not as large or as consistent as for mortality. Some studies also assess more indirect processes of cold exposure, e.g. falls among the elderly are more common in the winter, in part because of winter injury hazards such as ice, but possibly also because co-ordination is impaired by cold-reduced circulation.(13)

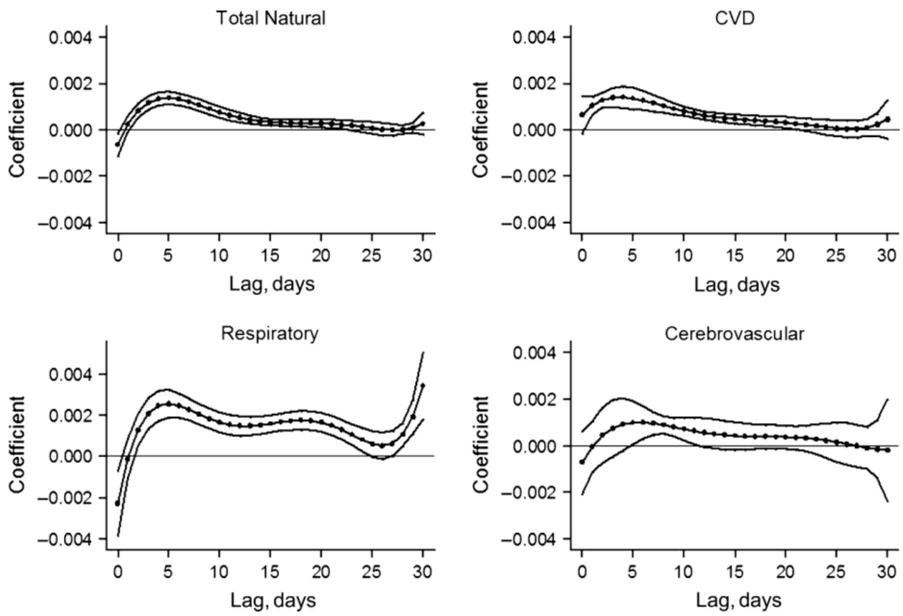

Figure 4. Distributed lags curves (and 95% confidence intervals) up to 30 days of the effect of a 1°C lower apparent temperature on daily number of deaths, during the cold season (October–March), 1990–2000.

In summary

- Time-series regression studies quantify the explicit health effects of weather factors, including outdoor temperature.

- In the UK, the current burden from cold weather is substantially larger than from hot weather.

- Cold-related deaths can be delayed by up to 4 weeks following exposure.

- There is evidence that some morbidity is also increased during cold weather.

1.3 Relative importance of indoor vs outdoor exposure [Concept piece 3]

As noted above, there is very strong evidence for excess mortality and some morbidity in winter and more specifically during cold periods for the UK and most non-tropical climates. However, the specific mechanisms and routes by which "exposure to cold" affects health outcomes are much less clear. Here we briefly summarize what is known about the extent to which low ambient temperature impacts on health through:

a) directly affecting people while they are outside
b) causing low temperatures or other changes inside buildings

Both these routes to ill-health and mortality are plausible and have been written up as likely explanations for the observed associations.

One source of evidence is in comparisons of severity of adverse low-temperature effects in different climates. In particular in Europe, adverse effects of low temperature on mortality are greatest (for a given low temperature) in countries with warm rather than those with cold climates. In Scandinavian countries and Northern Russia there is very little association of mortality with cold, despite – or perhaps because of – very cold outside temperatures. (14-16) Although this cannot give direct evidence for impacts outside or inside buildings, it does suggest greater physiological, behavioural or physical adaptation where cold is more common and is among the incentives to find the specific adaptations that are effective.

Keatinge, who wrote extensively on the subject of cold-related ill-health in the UK, emphasized "brief excursions outdoors rather than low indoor temperatures" as routes whereby cold impacts on health, and thus the importance of outdoor clothing and behaviour. (17, 18) Evidence cited in favour of the importance of clothing included an interview survey in the very cold setting of Yakutsk in Siberia, where there was very little excess mortality during coldest weather, and milder Yekaterinberg. In Yakutsk, respondents reported wearing more thermally effective clothing and not shivering during excursions – although houses were also well-heated.(16) An ecological study which considered societal determinants of increased mortality per degree of cold in six European communities found that greater increases were associated with communities wearing less "hats, gloves and anoraks" independently from an association with poorer home heating.(14)

Evidence for the importance of home heating in winter includes the European ecological study as noted above, and another by Keatinge which found that reductions in England in excess winter mortality from 1964 to 1984 were closely matched by increases in central heating, but not by changes in severity of influenza epidemics.(17) The only non-ecological evidence comes from finding much less excess mortality in residents of houses with some evidence of being well heated compared to those in houses likely to be poorly heated (see Figure 5). This study used the temperature measurements in the 1991 English House Condition Survey to characterise houses by extent of heating and these classifications were applied also to the surrounding postcodes, so the measure was approximate.(19)

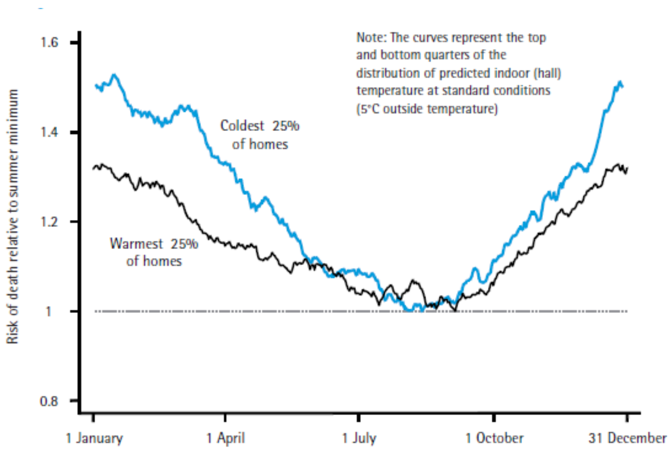

Figure 5: Seasonal fluctuation in mortality in cold and warm homes

In summary

- Both poor home heating and experience cold during excursions outside are plausible routes by which low ambient exposures might cause ill-health and death.

- Current evidence gives some support for each of these two routes of exposure, but is insufficient to determine the relative importance of each.

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