7 Illness and mortality from heat and cold: will global warming matter?

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How does cold and hot weather affect health and mortality?

In the first book produced in the European continent, Herodotus wrote, 'Change is the great cause of men falling sick, more particularly change of seasons'. Today, death rates still increase in winter, and they also increase during heat waves in summer. These increases still represent the principal adverse effect of environment on mortality, and they are largely avoidable. Mortality in European countries is at its lowest when mean daily temperature is around 17°C [1, 2] and it rises as temperature either falls or rises from that level. The numbers of these excess deaths per year give the best measures respectively of cold related and heat related mortality.

An older measure used to measure winter mortality was the number of deaths per million during the December to March period as an excess over the mean mortality rate during the rest of the year. That is simple to calculate, and often provides a rough comparison of winter mortalities at different times and in different regions, but this measure has major drawbacks. Its worst drawback is that it is determined by mortality due to hot weather as well as to cold. If there were more deaths due to hot weather in summer than to cold weather in winter, the calculation could suggest no winter mortality due to cold, although cold did in fact produce high mortality during the winter.

Throughout Europe, and also in most of the world, cold-related deaths are far more numerous than heat-related deaths. This is particularly true of Britain, which has around 40,000 cold related deaths per year compared to 1,000 heat related deaths per year.[3] About half of the cold related deaths are due to coronary and cerebral thrombosis (heart attacks and strokes), and about half of the remaining deaths are due to respiratory disease.[4]

The main reasons for these deaths are straightforward. Coronary and cerebral thrombosis in cold weather is caused by the blood becoming more concentrated, and thus more liable to clot when people are exposed to cold. That concentration is part of the body's adjustment after blood flow to the skin is shut down in cold conditions to conserve body heat.[5, 6, 7] The shift of blood from the skin produces an excess of blood in central parts of the body. In order to correct for the excess blood, salt and water are moved out from the blood into tissue spaces, and eventually excreted. This leads to increased levels of a variety of blood components that promote clotting. The blood also contains a substance called Protein C which hinders clotting, but this molecule is small enough to diffuse through the walls of blood vessels. As a result, it can redistribute through most of the tissue spaces of the body, and shows little increase in the cold. This selective concentration of clot-promoting factors in the blood causes little harm in young people, whose arteries are generally in good condition. However, it greatly increases the chance of a clot forming on rough patches of atheroma, which are common in the arteries of elderly people. Respiratory infections in winter also increase blood levels of fibrinogen, which further promote clotting.[8]

The increase in respiratory deaths in winter is due partly to respiratory infections, which spread more readily in cold weather. There are several reasons for this. People crowd together in poorly ventilated spaces when it is cold. Breathing of cold air stimulates coughing and running of the nose. Other reasons for the respiratory deaths are that cold stress tends to suppress immune responses to infections, and the mucosa (lining) of the airways seems to resist infection better if surrounding temperatures are warm. The old remedy of inhaling steam for approximately 30 minutes not only immediately reduces the symptoms of a cold, but moderates the entire subsequent course of the illness.[9, 10]

Severe influenza can cause fatal pneumonia directly, as well as through secondary infection. Epidemics of influenza used to kill many tens of thousands of people every two or three years. Since the 1970s, these epidemics have been much less common and less severe. The decline mostly occurred before the start of immunisation against influenza.[4, 11] It probably resulted from better hygiene, which reduced spread to man of new strains of avian influenza. Such spread is still limited to a degree, but new strains of influenza developing among chickens raised in large numbers in crowded conditions have recently caused large epidemics among these birds. There is a risk of these new strains developing the capacity for rapid transmission in man, and triggering human illness on the scale of the influenza pandemic of 1918.

Events leading to respiratory deaths in winter often start with a cold or some other minor infection of the upper airways. This spreads to the bronchi (the airways in the lungs), and to the lungs. Secondary infection then causes pneumonia. Surprisingly, hypothermia, the most obvious cause of death from cold exposure, is rare in peacetime. After influenza deaths declined in the 1970s, it was widely assumed that most of the remaining rise in mortality in cold weather was due to hypothermia, which involves simple cooling of the body until vital organs such as the heart and brain cease to function. In reality, cases of hypothermia are rare in Britain[12, 13] and probably throughout Europe.

Although it is straightforward that exposure to cold weather causes illness and death, evidence is needed to prove that cold causes most of the excess deaths in winter. It would theoretically be possible that some altogether different factor, such as vitamin deficiency in the winter diet, was responsible for many deaths. This was plausible, since vitamin C does have a protective action against arterial thrombosis. It is found particularly in fresh fruit and vegetables, which are most plentiful in summer and autumn, and scarcer in winter. Cheap fruit and vegetables, and particularly orange juice, are now freely available even in winter. However, other possible factors that have been suggested to cause winter mortality are absence of sunshine, and seasonal changes in lifestyle.

Positive evidence that cold causes most of the excess mortality in winter is provided by analysis of short term relationships between cold weather and daily deaths.[14] The standard method for examining relationships of that kind is time series analysis, a branch of statistics designed to show changes in one factor after a change in the other. In this case, the usual procedures used for that analysis were complicated by the fact that a fall in temperature one day is on average preceded by a rise in temperature on previous days. Thus it is difficult to establish whether the fall in temperature, or the earlier rise in temperature, causes a subsequent change in daily mortality. The solution was to evaluate changes in mortality after a cold day for the time of year, rather than to evaluate this change after a fall in temperature.

To carry out this evaluation, first a low pass filter was used to remove slow seasonal changes. Regression coefficients were then calculated, at successive days lag and advance, for daily temperature on temperature and then for daily mortality on temperature. It showed that spells of cold weather were accompanied by increases in mortality which continued for many days after the cold spells ended. Analysis in the linear temperature/mortality range 0 to 15°C provided evidence that the size of this mortality from short term effects of cold was large enough to account for all of the excess mortality in winter.

The time relationships of these mortalities to cold weather differed between causes of death. Coronary deaths peaked within one to three days of peak cold, but respiratory deaths peaked twelve days after peak cold. This fitted with coronary deaths being produced by the changes in blood composition observed in the cold. It also fitted with the respiratory deaths being due to cold, which promotes the spread of respiratory infections and exacerbates existing infections, which then progressed to cause fatal pneumonia many days later.

Surprisingly, much of heat related mortality in hot weather is also due to coronary and cerebral thromboses. This also results from haemoconcentration, but in this case it is due to loss of salt and water in sweat.[15] Other heat-related deaths result from a range of other factors which are not well understood, but include hyperthermia, and probably the strain on failing hearts when additional blood flow to the skin is needed to increase loss of heat from the body. One mitigating factor in heat-related mortality is that these deaths occur within a day or two of hot weather, and are followed by a lower than normal mortality. The likely reason is that many of those who die in the heat are already very ill, and even without heat stress would have died within the following two or three weeks.

How will global warming affect mortality?

There is now strong evidence that global warming has been under way for at least thirty years, and that it is largely man made and is continuing.[16] A large part of the warming is due to emissions of carbon dioxide from the burning of fossil fuels. Since there are fewer heat-related deaths than cold-related deaths, the overall effect of global warming could be expected to be a beneficial one. When it was recognised in the 1990s that global warming was under way, public attention inevitably shifted from the hazards of cold weather to those of hot weather.

The main concern at first was that diseases transmitted by insects, such as malaria, would spread to cooler regions of the world, and would become a serious problem in these areas. Closer examination showed that this was unlikely to happen. Malaria, for example, was once endemic in most of Europe, and even in Russia, but had already been eliminated. The main reason was that modern farming methods and changes in human living conditions had reduced the number of the mosquitoes that spread the disease, and reduced their opportunities to bite people[17]. There is no reason to

expect that global warming would bring a resurgence of malaria, even if summers became substantially warmer. For the same reasons, mosquitoes which carry *Falciparum* malaria, the most dangerous variety, are unlikely to spread from the tropics. If they did start to spread, spraying to kill mosquito larvae should control them.

Global warming could affect mortality through the more direct effect of temperature on people. If these are assessed on the assumption that particular degrees and patterns of heat or cold will continue to produce the same mortalities as they did previously, the additional deaths due to heat would be much smaller than the reduction in deaths due to cold. For Britain, on this assumption the rise in temperature of 2°C expected over the next fifty years would increase heat related deaths by about 2000, but would reduce cold related deaths by about 20,000.[3]

Of course, people who die as a result of heat would not be reassured by being told that fewer people would die next winter as a result of cold. Studies of populations that live in widely different climates showed that they had in fact adjusted to their own climates remarkably well. The Eurowinter study, with active surveys of 12,000 people in eight regions of Europe, showed that people in cold regions such as the north of Finland protected themselves so well from cold that they experienced no more winter mortality than people in regions with much milder winters such as London and Athens.[1] Heat-related mortality in Finland indicated similar adaptation – it was not significantly greater in the hot summers of Athens or London than in the north of Finland.[2]

Studies of actual changes in heat-related mortality since the advent of observed global warming show that as temperatures have risen, the increase in heat-related mortality produced by a particular level of high temperatures has fallen. Summer temperatures have risen at least 1°C both in London and in the subtropical region of North Carolina since 1971. However, heat-related mortality has not risen in London, and has virtually disappeared in North Carolina despite humidity also increasing there and wind decreasing.[18]

Studies in Siberia have strengthened the evidence that people adjust effectively to cold climates. Remarkably, there is little excess winter mortality there; there is none at all in Yakutsk, in eastern Siberia, the coldest city in the world with temperatures averaging -30 to -40°C in winter.[19]

The explanations are straightforward. The surveys showed that at a given outdoor temperature in winter, people in cold parts of Europe not only kept their houses warmer than people in warm parts of Europe, they also dressed more warmly and were more likely to keep moving when outside. People in Yakutsk wore massive fur clothing outdoors. The comparisons were made for the same outdoor temperature, and for people of the same ages. People in cold countries were simply much more effective in keeping warm in cold weather. At the same time, people in countries with hot summers seem to be more effective in protecting themselves from heat. The siesta of southern Europe is an obvious example. In North Carolina, a large increase in air conditioning in the region seems to be responsible for the virtual disappearance of heat related mortality.

The effect of warming on tropical countries close to the equator remains difficult to assess. These countries generally do not produce the daily mortality figures needed to estimate heat related mortality. Extraction of daily figures world wide will be needed for a full world wide assessment.

What should we do to protect health during European heat waves in the next decade?

It would be easy to look at these facts and say that we need do nothing, at least in Europe. Global warming is not likely to increase overall mortality, even in the short term. People will also make their own adjustments to hotter summers in time, and that will prevent increases in summer mortality in the long run.

In reality, there is much that we can and should do. Sudden heat waves can be expected to produce record high temperatures from time to time as the climate warms. These inevitably expose populations to higher environmental temperatures than they have ever encountered before. They are accordingly likely to cause high mortality for a few days, especially amongst people who are not prepared. Although deaths due to cold weather can be expected to fall by an amount which more than balances these deaths, people who might die in a heat wave will not be reassured with the knowledge that far fewer people are likely to die from cold in the winter.

Air conditioning can provide a comfortable indoor temperature in the most extreme heat waves, and it plays an important role in preventing heat related mortality in tropical and subtropical climates. It will be useful in buildings where elderly people reside in warm parts of Europe, at least as a reserve in heat waves if other methods fail. It is also helpful in maintaining efficient working conditions of temperate regions. Unfortunately, air conditioning also has drawbacks. The most important is high energy consumption, which requires increased generation of electricity, and this in turn is generally achieved by burning more fossil fuels. Air conditioning can also involve substantial capital cost in relation to the amount that it is used, particularly in temperate regions where severe heat waves are rare.

Alternative strategies are therefore important to supplement air conditioning in hot climates and to replace it in cool ones. Building regulations need to ensure that buildings are designed, or modified when necessary, to keep cool in hot weather. Suitable design can enable buildings to keep a more even temperature throughout the 24 hour cycle. Important elements in suitable building design are high thermal insulation in outer walls, high thermal mass internally, and protection against direct sunlight. It is particularly important to prevent sunlight from entering through windows, which causes greenhouse heating of houses. In Southern Europe, external slatted shutters are a traditional and effective way to prevent such overheating in houses. Windows are best kept closed after dawn for as long as the interior of a building remains cooler than the outside air, and so long as they do not cause heat stress to people inside.

Cooking should be kept to a minimum wherever it will warm indoor living spaces and increase humidity. Crowding of people indoors will also increase temperature and humidity.

Warnings to the public are important when severe heat waves are forecast, together with advice on how their effects can be mitigated. Broadcasting such forecasts and advice together will give time for people to ensure that fans and water are available and that windows can be opened. Once the interior of a building does become uncomfortably hot, a combination of light clothing, air movement from a fan, open windows, and sprinkling water on the clothing, can be used to reduce heat stress. People should continue to eat regular meals with moderate salt content and to drink water, even if they do not feel hungry or thirsty.

These measures will normally be effective even for people who are elderly, vulnerable because of illnesses such as diabetes, or people who are taking drugs that suppress sweating. Sprinkling water on clothing can substitute for sweating, and will allow evaporative cooling even in these people. Evaporative cooling also requires that the air should not be saturated. When heat stress develops, ventilating with air from an open window, together with the other measures, ensures that it will not be saturated, since outdoor air is not saturated at hot times of the day in European heat waves.

Anyone who becomes seriously overheated, with a mouth temperature around or above 40.5°C, needs to be cooled immediately rather than transported to an institution. This should be started at once rather than waiting for help from the emergency services. Immersion in a cool bath can be used if other measures are difficult to implement effectively. Extremely cold water will cause vasoconstriction, which can retard cooling, thus mild cooling should be the aim. A high proportion of those people who died in France in the 2003 heat wave appear to have died in institutions. Institutions which are treating the elderly and other vulnerable people need to dedicate special attention to protective measures against extreme heat.

Important as these measures are, we should not lose sight of the fact that cold weather causes more deaths than hot weather. The importance of warm housing in winter is well recognised, but the large contribution of outdoor cold stress to winter mortality [1, 20] is generally not equally recognised. Without action to address cold-related mortality, it is unlikely that global warming will reduce such mortality in the long run. Since people in regions with mild winters protect themselves less effectively against cold and generally experience more winter mortality than people in colder regions[1], climatic warming cannot on its own be expected to cause long term reduction in winter mortality. Active measures to reduce exposure to cold both outdoors and indoors will remain important.

The wider implications of global warming

The general conclusion is that the effects of rising temperatures on health and mortality are manageable and generally beneficial, at least in the medium term and over much of the world. A broader assessment would of course need to take account of other effects of rising global temperatures. For example, one estimate suggests that melting of the icecaps and warming of the oceans could raise sea level by 34 cm by the year 2100,[21] and they may cause widespread climate changes. Predictions of that kind are extremely controversial in detail, and need to be weighed against the cost in human and financial terms of reducing fossil fuel consumption or switching to nuclear energy. Even the Kyoto Protocol, which is still not agreed, would only slightly reduce global warming.

Notes

1 Eurowinter Group (1997).
2 Keatinge WR et al (2000).
3 Donaldson et al. (2001).
4 Keatinge et al. (1989).
5 Keatinge et al. (1984).
6 Neild et al. (1993).
7 Neild et al. (1994).
8 Woodhouse et al. (1994).
9 Ophir and Elad (1987).
10 Tyrrell et al. (1989).
11 Donaldson and Keatinge (2002).
12 Coleshaw et al (1986).
13 Woodhouse et al. (1989).
14 Donaldson and Keatinge (1997).
15 Keatinge et al. (1986).
16 Hulme et al. (2001).
17 Reiter (2002).
18 Donaldson et al. (2003).
19 Donaldson et al. (1998).
20 Keatinge (1986).
21 Titus and Narayanan (1996).

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