

COLD AND THE RISK OF CARDIOVASCULAR DISEASES

A review

The higher occurrence of cardiovascular diseases in winter is well known, and several explanatory mechanisms have been suggested based on increased blood pressure, haematological changes and respiratory infections. Most investigations have used ecological data such as daily temperatures recorded at weather stations and mortality in the general population. Cause-specific mortality is the outcome measure most commonly used. Local myocardial infarction community registers would offer an ideal database, but may suffer from inadequate statistical power. Hospital discharge records, linked with out-of-hospital deaths, provide a powerful tool for detecting even weak effects of temperature. The association of coronary heart disease and temperature is usually U-shaped, mortality being lowest within the range 15–20°C and higher on both sides of this. The increase in mortality on the colder side is in the region of 1% per 1°C fall in temperature, but the increase on the warmer side may be very steep. The exact location of the minimum temperature and the magnitude of the effect can vary between countries. In Finland the winter excess mortality from coronary heart disease has been levelling off during recent decades, but it still represents approximately 6% of annual deaths due to this condition.

Simo Näyhä, MD PhD

Oulu Regional Institute of
Occupational Health
Department of Public Health
Science and General Practice,
University of Oulu

There is a wealth of evidence showing that cardiovascular deaths in a population increase during the cold season of the year, and similar findings have been reported for the incidence of these diseases (1, 2, 4, 5, 18, 19, 23-25, 28, 32, 44, 45, 46). The patterns vary between countries (32), but negative findings are few (43). The reasons underlying the higher occurrence of cardiovascular conditions, particularly coronary heart disease, in winter have remained controversial, but investigators have mostly pointed to environmental cold (6-10), respiratory infections (2, 23) or both (5), or indirect effects of winter such as the work of shovelling snow (38).

The detailed mechanisms by which cold influences the pathogenesis of cardiovascular manifestations, directly or via respiratory infections, have not been clarified in full. Proposed mechanisms include ischaemia resulting from raised arterial blood pressure and the consequent increase in myocardial oxygen demand with a simultaneous decrease in coronary blood flow, and haematological changes following cold-induced vasoconstriction and consequent loss of plasma fluid, which predispose the subject to arterial thrombosis (11, 13, 14, 28, 31, 41, 45). Respiratory and other infections, viral and bacterial, which mostly occur in winter, may trigger attacks of coronary heart disease or stroke, as they affect blood coagulation factors (3, 42), cause damage to vessel walls and may promote atherosclerosis (42).

MEASUREMENT OF COLD EXPOSURE

The most common measures of exposure in epidemiological studies of cold and cardiovascular diseases have been monthly, weekly or daily temperatures recorded at one or more meteorological stations. Some works have used monthly average or monthly minimum temperatures, or several temperatures during the week (3), but recent works have often been based on daily average or daily minimum temperatures (12, 20, 26, 29, 30, 37), or on the number of days on which the temperature was below a pre-defined value (22). The significance of the duration of cold spells has been evaluated by Bull and Morton (8-10) and Wyndham and Fellingham (46). No large population-based study has used individual information on actual cold exposure, although one cross-sectional survey measured room temperature at the interviewees' homes and used personal information on

outdoor excursions, shivering and personal protective measures, linking this with cardiovascular disease mortality in the general population (20). In any case, measures of cold exposure used in epidemiological studies are indirect, and any results based on them may be more or less affected by aggregation bias resulting from observations derived from both the individual and population levels. Prospective studies based on individual data on exposure and outcome are lacking. In theory, such studies could clarify the long-term effects of cold, although it is true that it may be extremely difficult to control all possible confounding factors over a long follow-up time.

OUTCOME MEASURES

The majority of studies in this field are based on cardiovascular mortality derived from national, regional or local death records. A few investigators have separated in-hospital and out-of-hospital mortality (18) or made a separate study of sudden deaths (2, 40). An ideal measure of the occurrence of cardiovascular diseases is the incidence rate, which is available from community registers and has been used to study the seasonality of these conditions and their association with temperature (12, 40, 44). Hospital admission data are easily available and have been used for this purpose, their drawback being that cases dying before admission to hospital are not recorded. Linkage between national hospital discharge and death registers – which has been a possibility in Finland since the 1970's – provides access to massive databases and greater statistical power for identifying associations between temperature and cardiovascular diseases than could ever be achieved in the case of local community registers. It also allows a study of the entire time course of myocardial infarction and stroke in the whole population and the effect of temperature separately on incidence and survival at different phases after the attack. There have only been a few investigations into the effects of season or temperature on survival after myocardial infarction or stroke (40, 44).

Coronary heart disease and myocardial infarction are the diagnostic categories most commonly used, but a few studies have been able to differentiate between the first attack and subsequent attacks (4, 12, 23, 39), which may behave differently. A number of studies exist on cold affecting cerebral vascular accidents (6-10, 32, 36), mostly defining this disease category as one entity (stroke), but sometimes

separating cerebral and subarachnoidal haemorrhage and thrombosis (36, 37, 44). The reliability of the diagnoses used is rarely reported, e.g. percentages of diagnoses based on autopsy are not given, or are not known.

SHORT AND LONG-TERM EFFECTS

The effect of cold on cardiovascular diseases has been addressed mostly in terms of short-term temporal effects, i.e. days or weeks. No information on long-term effects is available. However, a few investigators have analyzed the long-term association between cold and cardiovascular conditions in a geographical context, in an effort to understand regional variations in diseases (22, 27). In Finland (33, 34) and Sweden (22), cold areas actually show much higher mortality from coronary heart disease than warmer areas, but the population living in the colder areas is also disadvantaged in other respects, which introduces collinearity into the data and hampers any identification of cold as an independent factor.

CORONARY HEART DISEASE

Investigations into the association between temperature and coronary heart disease mostly report an increase in deaths with lowering temperatures (2, 4-7, 10, 13-16, 19-21, 25, 28-30, 37, 38-39, 40), although some rise in mortality is seen at the warmer end of the temperature scale, which actually makes the pattern U-shaped (10, 25, 38). Mortality is usually lowest in the region of 15–20°C and rises both with lowering and rising temperature. In the USA, which represents a wide range of climates, the lowest mortality was seen in the temperature range 16–27°C (38), in Yekaterinburg, northeastern Russia, mortality increased only at temperatures lower than 0°C (16), and in Yakutsk, Siberia, the association was considered to be linear over the whole temperature range, from -48°C to +10°C (17). The increase in deaths on the warmer side of the temperature scale is steeper than the increase on the colder side, but the number of cold days and the absolute excess mortality during a normal year is greater than the number of hot days and heat-related mortality. Not all studies report a rise in deaths at warmer temperatures (6, 7, 12).

Some investigators have estimated the gradient expressing the increase in deaths per degree of fall in temperature below the mini-

imum for mortality. It is mostly estimated that mortality from coronary heart disease will increase by approximately 1% per 1°C fall in temperature (12, 20). Some studies (12), but not all (23, 39), have reported a stronger effect in the first infarction than in subsequent ones.

The association of coronary heart disease with cold varies between countries, being paradoxically weaker in colder regions of Europe than in warmer ones (20), and weaker in Canada (colder) than in England and Wales (milder) (2). In Yakutsk, Siberia, temperatures as low as -48°C had no effect on coronary mortality (17). Thus the association of coronary heart disease with environmental temperature is strongly modified by behavioural and social factors such as clothing patterns, outdoor behaviour and housing conditions, and cannot be expressed as a single estimate.

A few studies have described the time course of the temperature change leading to a change in mortality. Changes in temperature lasting two days or more in Britain are sufficient to cause an increase in mortality, while no such effect is seen after isolated cold days (8-10). A time-lag of 1 to 3 days (9, 14) has been reported to exist between the temperature change and death, and at least some excess mortality persisted during the subsequent 40 days (14). The long-term seasonal effect on deaths is believed to be smaller than the short-term effect, possibly due to a weakening of cardiovascular responses to cold during repeated exposures (14). The effect of temperature on case-fatality rates for myocardial infarction is not known, but case-fatality tends to be worse on cold days (40) or in cold months (18).

There is some indication that the effect of temperature on coronary heart disease has been levelling off in recent decades. The seasonal amplitude in mortality from heart disease in Finland has diminished since the 1920's (32), and the proportion of deaths attributable to the cold season (September to March vs. August), which was 9% in the early 1960's, had diminished to 6% over the subsequent 30 years (35). This can be regarded as an indirect indication that the effect of cold on coronary deaths has weakened. The gradient of deaths relative to temperature among old people in England and Wales had similarly diminished during the period 1977 to 1994 (15).

CEREBLAR VASCULAR ACCIDENTS

The association of environmental temperature with cerebral vascular accidents is somewhat similar to that found for coronary heart disease, the numbers of deaths and incident cases increasing with declining temperature (6, 7, 10, 16, 20, 36, 37, 38). The pattern is often U-shaped, with some increase in numbers at warmer temperatures (10, 36-38). The mortality or incidence of stroke is usually lowest at temperatures in the range 15-20°C, but there are variations. In northeastern Russia mortality increases only at temperatures below 0°C (16) .

The gradient of cerebral vascular accidents against temperature is of the magnitude of 1% per 1°C fall in temperature (20), as is the case with coronary heart disease. In Japan, the dose-response relationship was similar for intracerebral haemorrhages and cerebral infarctions (36), whereas in Finland a greater winter excess has been observed in the incidence of intracerebral haemorrhage than in other forms of stroke (44), but no gradient relative to temperature has been reported.

A change in temperature of at least 2 days' duration is needed for stroke mortality to rise, and the time-lag between the temperature change and the maximal increase in mortality is estimated to be 1-4 days (8).

No information is available on the effect of temperature on case-fatality figures for stroke.

The long-term temporal trends in the effect of temperature on stroke have not been determined, but the seasonal amplitude of stroke deaths in Finland has diminished since the 1920's (36). The proportion of deaths attributable to the cold season was estimated to be 13% in the 1960's, but this had diminished to 9% by the 1990's (35). A British investigation reporting a decline of 57% in the stroke-temperature gradient over the period 1977-1994 (15) similarly suggests that the effect of environmental temperature on stroke is being modified by external factors.

SIGNIFICANCE OF COLD-RELATED CARDIOVASCULAR DEATHS

Some 3500 extra deaths occur during the winter season in Finland, of which 900 are certified as being due to coronary heart disease and 500 to stroke. The size of the problem is shown by a comparison with traffic deaths, which amount to 400 cases annually. This excess mor-

tality is preventable, and while being smaller in Finland than in warmer countries, its elimination should lead to substantial increases in longevity. Further research should focus on clarifying 1) the long-term effects of cold, 2) the role of respiratory infections, and 3) the significance of humidity, precipitation and atmospheric pressure in cardiovascular diseases.

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Simo Näyhä, Professor, MD, PhD
 Department of Public Health Science and
 General Practice
 P.O. Box 5000
 90014 University of Oulu, Finland
 phone +358-8-537 5671
 mobile +358-40-564 6159
 fax +358-8-537 5661