The relationship between mortality caused by cardiovascular diseases and two climatic factors in densely populated areas in Norway and Ireland

Helene Eng and James B. Mercer

Background Seasonal variations in mortality due to cardiovascular disease have been demonstrated in many countries, with the highest levels occurring during the coldest months of the year. It has been suggested that this can be explained by cold climate. In this study, we examined the relationship between mortality and two different climatic factors in two densely populated areas (Dublin, Ireland and Oslo/Akershus, Norway).

Methods Meteorological data (mean daily air temperatures and wind speed) and registered daily mortality data for three groups of cardiovascular disease for the period 1985–1994 were obtained for the two respective areas. The daily mortality ratio for both men and women of 60 years and older was calculated from the mortality data. The wind chill temperature equivalent was calculated from the Siple and Passels formula.

Results The seasonal variations in mortality were greater in Dublin than in Oslo/Akershus, with mortality being highest in winter. This pattern was similar to that previously shown for the two respective countries as a whole. There was a negative correlation between mortality and both air temperature and wind chill temperature equivalent for all three groups of diseases. The slopes of the linear regression lines describing the relationship between mortality and air temperature were a lot steeper for the Irish data than for the Norwegian data. However, the difference between the steepness of the linear regression lines for the relationship between mortality and wind chill temperature equivalent was considerably less between the two areas. This can be explained by the fact that Dublin is a much windier area than Oslo/Akershus.

Conclusion The results of this study demonstrate that the inclusion of two climatic factors rather than just one changes the impression of the relationship between climate and cardiovascular disease mortality. *J Cardiovasc Risk* 7:369–375 © 2000 Lippincott Williams & Wilkins.

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Department of Medical Physiology, University of Tromsø, Tromsø, Norway.

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Correspondence and requests for reprints to James Mercer, Department of Medical Physiology, Institute for Medical Biology, Faculty of Medicine, University of Tromsø, N-9037 Tromsø, Norway.
Tel: +47 77 64 4869; fax: +47 77 64 5440;
e-mail: jamesm@fagmed.uit.no

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Introduction

Mortality due to cardiovascular disease (CVD) is the most common cause of death in the Western world. Although the per-capita mortality rate due to CVD varies a great deal between different countries, seasonal variation in mortality has been described in nearly all countries in Europe as well as in other parts of the world [1–4], with the highest levels occurring during the winter. A higher CVD mortality has also been described in the northern and, therefore, coldest part of the country in several European countries [5–9]. A strong negative correlation has been shown between air temperature and CVD mortality in nearly all countries so far examined [2,10–15].

There is large variation in the size of the seasonal fluctuations in those countries in which excess winter mortality has been documented. For example, in Europe a high relative level of excess winter mortality has been reported in Great Britain [1,2,16], whereas relatively low levels have been reported in Scandinavian countries [1,2]. Ironically, the seasonal fluctuations in many Mediterranean countries are greater than those reported for Scandinavian countries [1], despite the fact that the mortality rate per capita on a yearly basis is low in these warmer countries [17]. We found similar results concerning excess winter mortality in Norway and Ireland in a previous study. These countries have a similar demography with respect to population and CVD mortality. Despite the colder winter climate in Norway, the excess winter mortality was greater in Ireland [18].

In a comparative study of eight areas in Europe, it was shown that the coldest areas (Finland) had a lower increase in mortality per degree centigrade decrease in air temperature compared to the warmest areas (Italy and Greece) [19]. However, this study showed that people in the coldest areas were better protected against the low outside air temperatures than people living in warmer areas. The areas with the lowest winter air temperatures had the highest indoor temperatures and people in these areas wore the best insulated clothes in the winter. It was therefore suggested that the differences in the size of the seasonal variations in CVD mortality in Europe can be explained by factors such as differences in housing standards as well as thermoregulatory behaviour. This view was further supported in a more recent study from eastern Siberia [20].

There are several well-known risk factors for CVD which show seasonal variations. Arterial blood pressure, plasma fibrinogen, blood viscosity and total cholesterol are all known to be elevated in winter [21–26]. In addition, experimental exposure to low ambient temperatures is known to result in increased arterial blood pressure, blood viscosity, cholesterol and haematocrit and an increase in some coagulation factors [27–31]. These observations, in combination with the epidemiological data described above, indicate that exposure to cold may in some way be partly responsible for the increased winter mortality.

Most of the above-mentioned epidemiological studies which were concerned with the relation between CVD mortality and climate only concentrated on the effect of air temperature. Quite clearly, only using air temperature as the independent variable is an oversimplification since there are other variables involved in determining climatic conditions. One such factor is wind speed. Excess winter mortality has been separately related to both air temperature and wind speed. These results have indicated that increased wind speed adds to the effect of cold temperature [32,33]. In one study in which the relationship between CVD mortality and both air temperature and wind chill temperature equivalent (WCTE) was examined, there was a better association between WCTE and mortality than between air temperature and mortality [34].

In our previous comparative study on winter mortality in Ireland and Norway, our analysis was based on monthly mortality data and mean monthly air temperatures for each respective country [18]. In an attempt to define the effect of climatic conditions on CVD more clearly, we restricted the data analysis in this study to two relatively small but densely populated areas in Ireland and Norway, namely Dublin and Oslo/Akershus. We examined daily climatic data and mortality data for these areas. In addition to examining the relationship between CVD mortality and air temperature, we also included an examination of the combined effect of temperature and wind speed, that is the WCTE.

Methods

Data

Registered population data and daily mortality data for three groups of CVD using the ninth revision of the International Classification of Diseases (ICD-9) (see Table 1) were obtained from the Norwegian Central Bureau of Statistics for the two neighbouring counties of Oslo and Akershus (hereafter referred to as Oslo/Akershus) in Norway. Likewise, population data and mortality data were obtained from the Irish Central Statistics Office for County Dublin (hereafter referred to as Dublin) in Ireland. The mortality data included deaths of men and women in the age group 60 years and older for the 10-year period 1985–1994.

Table 1 **The three groups of CVD studies and their respective ICD-9 codes**

Disease	ICD-9
All cardiovascular diseases	390–459
Acute heart infarction	410
Stroke	433–437

During 1985–1994, the average population in Dublin was 1 056 666 and the average population density 1147 inhabitants km^{-2}. The average population for the same time period was 953 183 and the average population density 190 inhabitants km^{-2} in Oslo/Akershus (Oslo 499 693 and 1170 inhabitants km^{-2}, respectively).

Meteorological data was provided by the Norwegian Meteorological Institute in Norway and Met Eireann in Ireland. These data contained mean daily air temperatures and mean daily wind speeds from weather stations in Oslo and Dublin. The WCTE, which includes the effect of both wind and temperature, was calculated from the Siple and Passels formula [35] as:

$$WCTE = 33 - \frac{(12.12 + 11.6\sqrt{v} - 11.6v)(33 - t_a)}{27.81} \quad (1)$$

where t_a is the air temperature and v is the wind speed

Mortality ratio

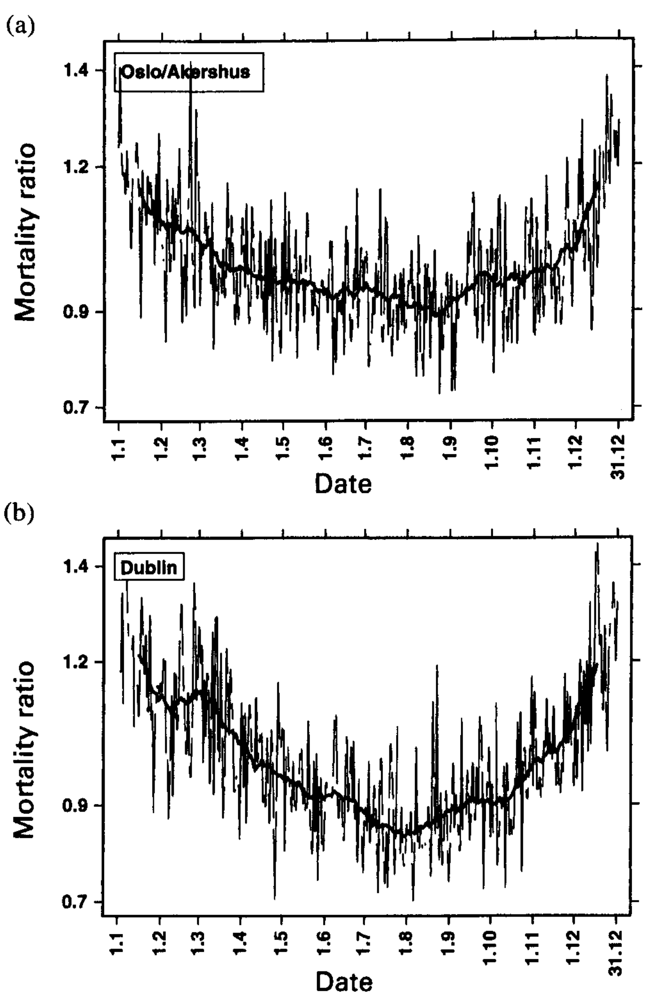
The mortality ratio (MR) was used to compare the relationship between climate and mortality for different groups of diseases with different mortality rates. In order to calculate the MR, the mortality for a given day was divided by the average daily mortality for the whole year:

$$MR = \frac{\text{Number of deaths in a given day}}{\text{Mean daily number of deaths for the whole year}} \quad (2)$$

Thus, for example, an MR of 1.2 for a particular day represents a death rate which is 20% greater than the average daily mortality for the whole year (MR = 1.0). In the presentation of the seasonal changes in CVD mortality, each data point is the 10-year MR average of a particular date. Data for 29 February 1988 and 1992 were excluded. Curve smoothing was applied to the data presented in Fig. 1 using a 31-point moving average in which the average value calculated for a particular day includes the value for that day as well as the values of the previous 15 days and the following 15 days. With this technique, the first value in the year falls on 16 January and the last on 16 December. A percentage value of the summer–winter difference in mortality was calculated as the difference between the lowest and highest daily moving average mortality values.

In order to investigate the relationship between mortality and climate, regression analyses were performed between the MR and air temperature and between the MR and WCTE. The daily mean air temperature and WCTE were rounded off to whole degrees and the mean MR was then calculated for each air temperature and WCTE. Since there were few data points for those days having the lowest air temperatures and WCTEs and since the MR increased at the highest air temperatures and WCTEs, which was probably due to heat stress, this outlying data was excluded from Figs 3 and 5. Thus, each data point included in these figures represents a minimum of 30 days with the same temperature or WCTE. The regression analyses between the MR and temperature were therefore limited to temperature intervals of −8 to 15°C and 1 to 15°C for Oslo and Dublin, respectively. Likewise, the WCTE intervals were −2 to 18°C and −5 to 18°C for Oslo/Akershus and Dublin, respectively. A *t*-test was used for testing the differences in the slopes of the regression lines and the Spearman correlation coefficient was found for each correlation. Differences were considered significant when $P < 0.05$.

Fig. 1



Average MRs for each date of the year for Oslo/Akerhus (a) and Dublin (b). The average values are calculated from mortality data for the years 1985–1994 for men and women of 60 years and older. The thick lines in both panels show the dates for the two areas and are presented with a moving average of 31 days.

Results

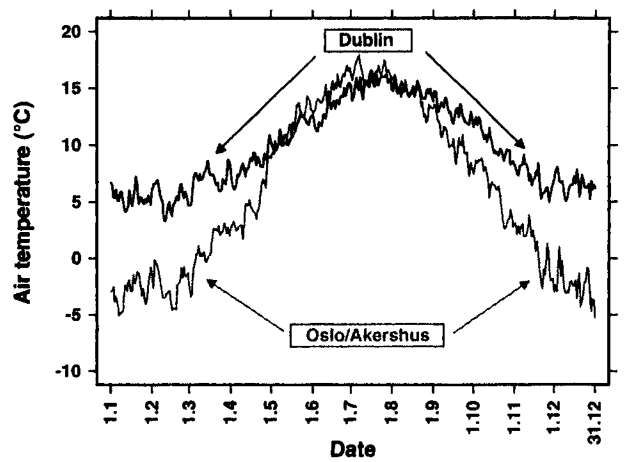
Figure 1 shows the mean daily CVD MR for each date in the 10-year period. The two panels show that there were greater seasonal variations in CVD mortality in Dublin than in Oslo/Akershus. This difference becomes clearer in the smoothed data presented in each panel, with winter–summer differences in CVD mortality of 27 and 38% in Oslo/Akershus and Dublin, respectively.

The mean daily air temperatures for Oslo and Dublin during the 10-year period are shown in Fig 2. The figure clearly shows the much lower winter temperatures in Oslo than in Dublin. The average daily temperatures in summer were quite similar in these two areas.

Figure 3, which in effect is a combination of the data in Figs 1 and 2, shows the relation between air temperature and CVD mortality for the two areas and the three different groups of CVD. All correlations are statistically significant. The regression between air temperature and the MR was statistically significantly steeper for Dublin than for Oslo/Akershus for all three groups of CVD. On the other hand, the slopes of the lines of the three CVD groups investigated for each area were not statistically significantly different from each other.

Figure 4 shows the mean WCTEs for Dublin and Oslo for each date in the 10-year period 1985–1994. Because

Fig. 2



Average air temperatures calculated for the 10-year period 1985–1994 for each date of the year for Oslo/Akershus and Dublin.

it is a lot windier in Dublin than in Oslo, the WCTE was always lower in Dublin than in Oslo, the difference between these two areas being most evident in the summer months.

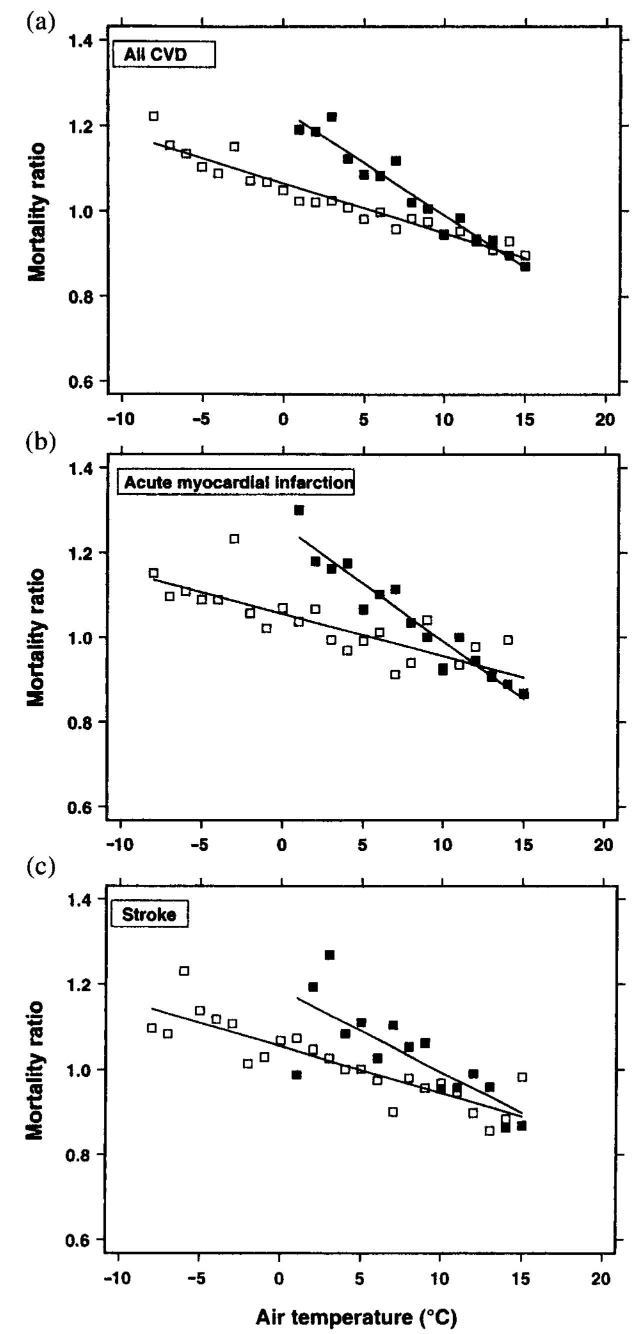
The relation between the WCTE and CVD mortality is shown in Fig. 5. The slopes of the regression lines describing this relationship for the three different CVD groups were statistically similar to each other for each area. The slopes of the regression lines between Oslo/Akershus and Dublin for each CVD group appear to be very similar in each of the three panels in the figure. However, this could only be statistically verified for the stroke group.

Discussion

In general, the results of this study, in which we examined seasonal variations in mortality from CVD using daily mortality data from Dublin, Ireland and Oslo/Akershus, Norway, show very similar trends to those shown in an earlier study in which we compared the seasonal variations in CVD for Ireland and Norway [18]. As in our previous study, which was based on mean monthly data for both countries as a whole, the seasonal fluctuations in CVD mortality were greater in Dublin than in Oslo/Akershus (Fig. 1). The winter–summer percentage differences for daily mortality from all CVD in these smaller areas were almost the same as the values for both countries as a whole (27 and 22% for Oslo/Akershus and Norway, respectively and 38 and 35% for Dublin and Ireland, respectively).

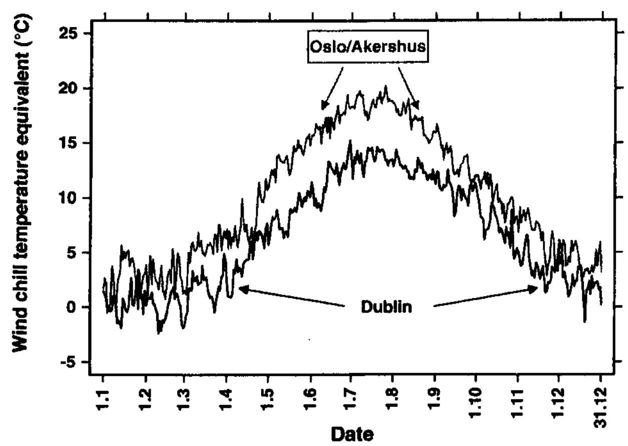
It has been suggested that exposure to cold in the winter may in some way explain excess winter mortality [2,10–13,15,19]. At first sight it may seem surprising that the Dublin area, which had the greatest fluctuation in CVD mortality, actually had the mildest winter climate in terms of air temperatures. This difference between Oslo/Akershus and Dublin with regard to the relation between air temperature and CVD mortality becomes clearer in Fig. 3. The significantly greater

Fig. 3



The relationship between the MRs from three groups of CVD and air temperatures in Oslo/Akershus (□) and Dublin (■) for the 10-year period 1985–1994. The mortality data are for men and women in the 60 years and older age group.

Fig. 4



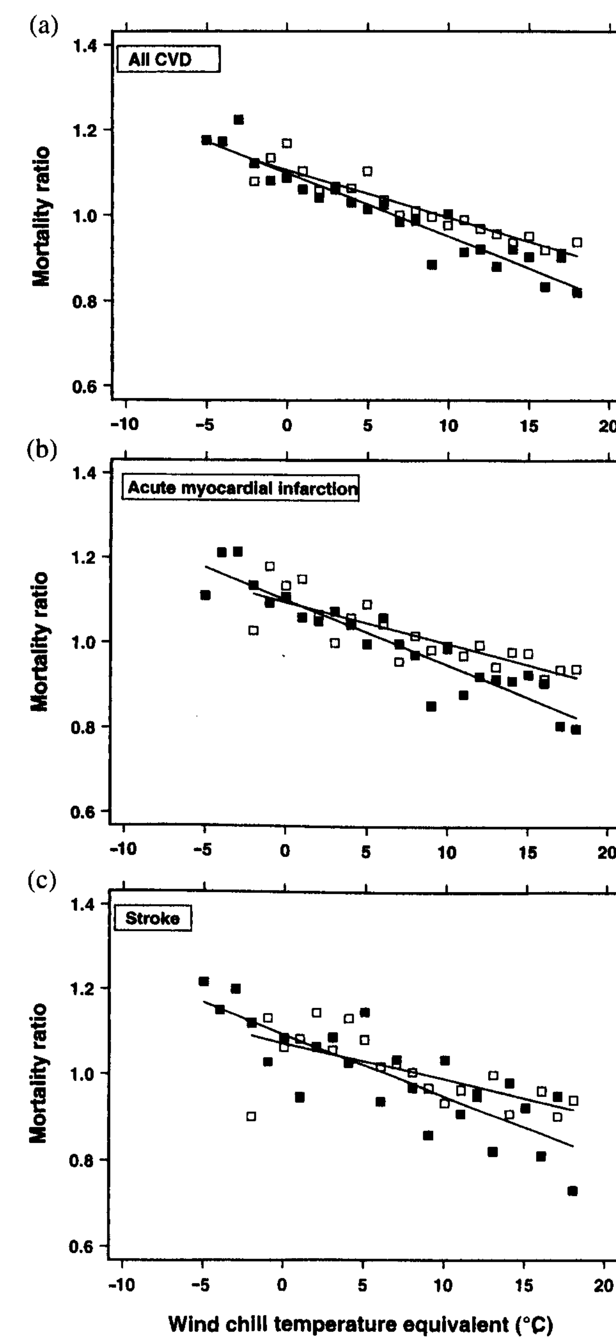
The average WCTEs calculated for the 10-year period 1985–1994 for each date of the year for Oslo/Akershus and Dublin.

increase in Dublin than in Oslo in mortality per degree centigrade decrease in air temperature is very similar to that seen for the two countries as wholes [18]. The slopes of the lines describing this relationship for acute myocardial infarction and stroke were the same as for all CVD for each respective area. In general, these findings are similar to those reported in the Eurowinter Study [19]. That study suggested that the greater effect of outside air temperature on CVD mortality in countries having milder winter climates was due to differences in protection (e.g. clothing habits) against outdoor exposure to low temperatures as well as to differences in indoor climatic conditions (house quality). While it is possible that both explanations are involved it has to be remembered that, during the winter months, people spend most of their time indoors, particularly elderly people and that the indoor climatic conditions may be the more important factor.

Although we investigated the relation between air temperature and CVD mortality in small areas, there will of course be local climatic variations within these chosen areas. However, it was felt that possible inaccuracies due to local variations in climate would be relatively small compared to previous studies in which data from whole countries or large parts of a country were investigated [33,36].

Clearly, using air temperature as the only climatic variable when examining the effect of climatic conditions on mortality from CVD may be an oversimplification and other climatic variables should also be taken into consideration. In an attempt to address this problem we also examined the combined effect of wind speed and air temperature on CVD mortality. We felt that this was particularly appropriate in this study since Dublin is a much windier area than Oslo/Akershus. That Oslo/Akershus is an area with little wind can be seen from the fact that the respective curves describing the daily variations in air temperature and WCTE throughout the year for the Oslo/Akershus data are very similar in shape (Figs 2 and 4). The mean daily wind speed in

Fig. 5



The relationship between the MRs from three groups of CVD and WCTEs in Oslo/Akershus (□) and Dublin (■) for the 10-year period 1985–1994. The mortality data are for men and women in the 60 years and older age group.

Oslo during the 10-year period was 2.5 kn. On the other hand, the mean daily wind speed in Dublin during the 10-year period was 10.1 kn.

There has been some discussion concerning the use of different wind chill formulas [34,35]. In addition to the Siple and Passels formula [35], the Steadman wind chill index is sometimes used by weather stations. The Siple and Passel formula is based on experimental results with freezing water in different weather conditions. The main criticism against this formula is that it does not take into account insulation due to clothing and the fact that humans produce heat. This formula should therefore only be applied to bare skin. The Steadman formula is a theoretical formula based on the heat balance equation which also takes insulation of the body with clothes into account. This equation is based on the situation when a fully clothed person is walking outdoors. The criticism against this method is that it has not been empirically tested. None of situations that these formulas are based on were ideal for our study. Steadman's formula is very complicated and takes into account factors that we did not have available, such as skin temperature, clothing resistance and the surface resistance of the body. It was for this reason that we chose to use the simpler Siple and Passel formula.

The low wind speed in Oslo is the reason why the regression coefficients for the Oslo/Akershus data do not change considerably between the temperature analysis (Fig. 3) and the analysis which included the WCTE (Fig. 5). On the other hand, the regression coefficients for the Dublin data are considerably lower for the lines in Fig 5 than they are for those in Fig 3. The slopes of the regression lines are more similar between the two countries when the relation between mortality and climate was analysed with respect to the WCTE rather than air temperature. However, while they appear to be similar, the regression lines are still significantly steeper for the Dublin data with regard to all CVD and acute myocardial infarction.

While it seems that both the Siple and Passels formula and the Steadman formula [34] may overestimate the effect of wind speed and may not be ideal for clothed persons living indoors, it was nevertheless felt that the principle trends of the results in this study are the most important. Part of the reason for the greater seasonal fluctuations in CVD mortality in Dublin compared to Oslo/Akershus may be due to the fact that Dublin is such a windy area. The difference between Oslo/Akershus and Dublin with regard to the relationship between CVD mortality and cold was reduced in the analysis where cold was represented as a combination of air temperature and wind speed as compared to the analysis where cold was only represented by air temperature. If we had used a wind chill formula that was less influenced by wind speed the reduction in this difference would have been smaller. In other words, the difference between the slopes of the regression lines between Oslo/Akershus and Dublin in the WCTE analysis would have been greater but still reduced compared to the difference in the air temperature analysis.

This study describes the relation between two outdoor climate factors and CVD mortality. The results support the suggestion that indoor climatic conditions rather than the outdoor climate are the most important factor in explaining excess winter mortality. The reason behind this suggestion is based on considerations as to how the outdoor climate influences the indoor environment. In general, it is considered that the standard of housing in Norway is better than in Ireland, in particular with respect to insulation and heating habits. Thus, the influence of both wind and low outside air temperature will presumably havé a much more pronounced effect on the indoor climatic conditions in Irish dwellings as compared to Norwegian dwellings. Other factors such as socioeconomic factors, health status, heating habits, etc., are also involved and clearly show that the picture is quite complex. To illustrate this fact, two recent studies were carried out in order to assess more clearly the differences between Ireland and Norway in indoor climatic conditions in a selection of houses inhabited by elderly people. The results showed a clear trend, Norwegian houses being much warmer and dryer than Irish homes (J. B. Mercer, personal communication) [37]. In conclusion, the slopes of the lines describing the relationship between air temperature and mortality from CVD are steeper in Dublin than in Oslo/Akershus. In an attempt to allow for the effect of wind by relating mortality to wind chill the apparent differences were reduced.

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