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Short-term relationships between winter temperatures and cardiac disease mortality in Cape Town

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The short-term relationship between winter temperatures and cardiac disease mortality in Cape Town was investigated for the period 1978 - 1985. The mortality data were stratified according to age (0 - 4 years, 5 - 59 years, 60 years and older), while the temperature data comprised daily maximum and minimum temperatures at Cape Town International Airport. The analyses identified a strong lagged relationship between extreme (high and low) temperatures and daily mortality, and it was established that large daily temperature variations were associated with above-average mortality rates.

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Cardiovascular disease is the leading cause of death among white, coloured and Asian South Africans.[1] According to 1986 statistics, it accounts for approximately 40% of all natural deaths in these population groups (whites 46%; Asians 43%; coloureds 26%). Among blacks, deaths due to 'symptoms, signs and ill-defined conditions' are most prevalent, followed by those resulting from infections and parasitic diseases. Diseases of the circulatory system rank third (15%) as a cause of natural deaths, and accounted for 11 367 deaths in 1986.[1]

In most countries, cardiovascular disease mortality (CDM) has a seasonal distribution, peaking during winter.[2] A number of studies have, in fact, linked rises in CDM to cold weather.[3-18] Although these associations are most marked when temperatures are abnormally low, moderate temperature falls are also at times accompanied by small peaks in mortality.[18] Similar trends in CDM have been noted during heat waves.[2,3,19-24] Furthermore, studies of CDM patterns during both heat waves and cold waves have revealed that the amount by which the temperature deviates from the mean is more closely linked to increases in mortality than any absolute temperature value.[2,22] The magnitude of the mortality increase also appears to be associated with the suddenness of onset of severe weather[25,26] and with its duration.[27-30] However, while the

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relationship between coronary heart disease and biobehavioural and environmental influences has often been documented, the exact mechanism is not clear.[31,32]

This paper examines the possible effect of short-term temperature changes during winter on CDM in Cape Town for the period 1978 - 1985. Extreme cold and hot (berg wind) conditions, as well as the effect of daily temperature fluctuation on CDM, are investigated. The temperature data comprise daily winter minimum and maximum temperatures supplied by the South African Weather Bureau (Pretoria) for Cape Town International Airport, for the period 1960 - 1988. The mortality data (1978 -1985) for Cape Town were extracted from computer tapes supplied by the Central Statistical Services. These processed data consisted of daily values for all diseases of the circulatory system, i.e. classes 390 - 459 according to the International Classification of Diseases of the World Health Organisation, and include, *inter alia*, rheumatic fever and chronic heart disease (390 - 398), hypertensive diseases (401 - 405), ischaemic heart disease (410 - 414), diseases of the pulmonary circulation and other forms of heart disease (415 - 429), cerebrovascular disease (430 - 438), as well as other diseases of the circulatory system (440 - 459).[33] The data provided were stratified by age groups as follows: 0 - 4 years, 5 - 59 years and 60 years and over (60+). Since research has shown that the aged are most affected by temperature extremes,[13,27,28] only data for the 60+ age group were utilised for the analyses in the present study. Given the relatively small size of the Asian community (1,2% of the Peninsula population),[15] as well as the unreliability of data on the black population groups,[34] it was decided to exclude these groups from the study. Only the mortality data pertaining to the white and coloured population groups were therefore used.

Methods and discussion

CDM and extreme cold

If CDM is indeed affected by excessively cold conditions, it follows that peaks in mortality should coincide with the occurrence of extremely low temperatures. Testing of this assumption clearly requires that the terms 'extreme cold' and 'extreme low temperature(s)' be defined first.

A long-term temperature distribution is usually assumed to be normal. 'Extreme' cold events can thus be defined in terms of Z-values (i.e. standardised deviations from the normal).[8,35-37] From this, estimates can be made of the probability of the occurrence of temperatures below a specific value. However, minimum July temperatures at Cape Town International are not distributed normally, and a distinct bimodality is evident (Fig. 1). This can probably be ascribed to the mid-latitude frontal activity which prevails in the south-western Cape in winter. It is likely that the higher peak reflects pre-frontal warm conditions while the mode at the lower temperatures is associated with post-frontal cold weather. The absence of normality precludes the use of Z-values and instead percentiles were used to delimit extreme values. The 20th percentile was selected for this purpose. Analysis of the 1960 - 1986 minimum temperatures at Cape Town International indicated that July minimum temperatures of < 4°C could be considered as reflecting 'extreme cold conditions'.

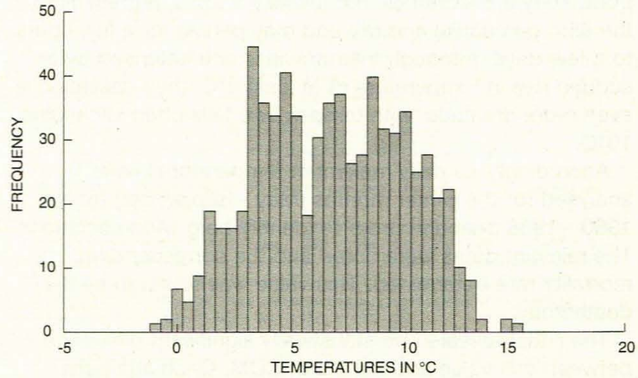

Fig. 1. Distribution of minimum July temperatures at Cape Town International Airport.

The *t*-test was used to determine whether the mean daily CDM (for the whole population) as recorded during extreme cold events differed significantly from that for the milder days. Daily July CDM values for 3 randomly chosen years, viz. 1978, 1984 and 1985, were used for this purpose. These means (9,06 for extreme cold and 8,8 for milder conditions) did not differ significantly, which implies that no significant rise in CDM occurred on the extremely cold days.

This result is not entirely unexpected since studies conducted in New York showed that the greatest number of deaths associated with a heatwave occurred 2 days after the highest temperature was recorded.[8,16,30] Bull and Morton[28] also identified a lag effect, but found that temperatures 1 - 4 days before the clinical onset of infarction were found to be more relevant than that on the day of onset. Therefore, the possibility of a lag in the association between extremes in minimum temperature and peaks in CDM was investigated. The *t*-test was used to examine 1-, 2-, 3- and 4-day lags. It was found (Table I) that the 2-day lag between CDM and extremely cold temperatures was statistically significant at the 90% level ($\alpha = 0,1$).

Table I. Average deaths following an extremely cold day

Days	Average deaths	SD
Extremely cold day	9,41	3,10
Lag 1	9,06	3,42
Lag 2	10,00	3,12
Lag 3	9,12	3,22
Lag 4	8,65	2,50

This implies that during the study period CDMs were significantly higher 2 days after the occurrence of a minimum temperature of 4°C or less. Although an entirely satisfactory explanation for this lag is not evident, it may reflect the period during which the body attempts, albeit unsuccessfully, to re-establish homeostasis after a cold 'shock'.

CDM and berg winds

The possibility of a link between the sudden onset of hot conditions and CDM was also investigated. Cape Town experiences some of its highest maximum temperatures during the winter months. This curious anomaly is the result of berg wind warming.[38] Berg winds are always associated with coastal lows and usually herald the approach of a cold front. They are extremely hot (usually > 25°C, representing the 95th percentile) and dry and may persist for a few hours to a few days. Although their arrival is characterised by a sudden rise in temperature of at least 5°C, their cessation is even more dramatic, with temperature falls often exceeding 10°C.

Accordingly, all daily maximum temperatures were analysed for the winter months (May - September) for the 1960 - 1988 period in order to identify berg wind conditions. The relevant dates were noted and the corresponding mortality rate determined. This value was found to be 8,27 deaths/day.

The *t*-test revealed no statistically significant difference between this value and the mean CDM. Once again the possibility of a lag effect was examined. The CDM was compared with the mean CDM of the day following the berg wind (lag 1), as well as for the 2nd (lag 2), 3rd (lag 3), and 4th days (lag 4) succeeding the berg wind event. The results (Table II) indicate that the 2-day lag's mean CDM (10,3 deaths/day) differs most from the long-term mean (8,72 deaths/day); the *t*-test showed the difference to be significant at the 0,005% level. This result thus accords with findings elsewhere.[8,16,30]

Table II. Average deaths following a berg wind day

Days	Average deaths	SD
Berg wind day	8,27	2,66
Lag 1	8,97	2,54
Lag 2	10,30	3,13
Lag 3	8,70	2,72
Lag 4	8,67	3,10

It is clear that the effect of berg winds on human health should not be underestimated. The unusual heat associated with berg winds is likely to cause thermal stress, especially in individuals with defective thermoregulatory systems. Moreover, the suddenness of onset of these conditions does not allow time for acclimatisation, even in healthy individuals. According to Leithead and Lind,[18] '. . . the primary physiological failure in an unacclimatised man suddenly exposed to high heat stress probably lies in the failure of the sweating mechanism. But it is also true that in such conditions any heat disorder that develops is most frequently cardiovascular in origin. Because of the poor response of the sweating mechanism, an even greater responsibility is put on the cardiovascular system to try to dissipate heat against an uneconomical internal bodily gradient from the core to the periphery.' In the case of people suffering from serious heart complaints, this 'greater responsibility' imposed on their weakened cardiovascular systems may result in the collapse of these systems. A temperature of 27°C, which is pleasant and not unusual in summer, may thus be critically stressful in winter.

CDM and diurnal temperature variation

Strong associations have been identified between short-term upswings in mortality and low air temperature in various parts of England and the USA.[26,27,30] This aspect was examined for Cape Town. The diurnal temperature range (i.e. maximum temperature minus minimum temperature) was deemed to reflect such a sudden temperature change. Accordingly, the daily temperature range was determined for each day during July, 1978 - 1985. These were grouped into various classes, viz. 0 - 5°C; 6 - 10°C; 11 - 15°C; 16 - 20°C; and 21 - 25°C whereafter the mean daily CDM (total, population) was calculated for each temperature range class. The results are depicted in Fig. 2.

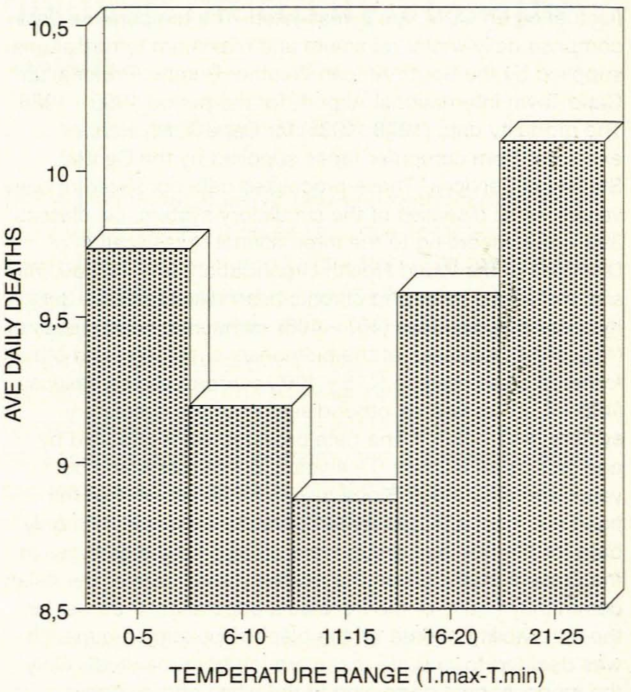

Fig. 2. Cardiac disease mortality for various daily temperature ranges.

Analysis of daily temperature ranges revealed that daily maximum and minimum temperatures in July usually differ by between 10,3°C and 11,2°C in Cape Town. It is notable that the mean CDM is lowest during such conditions, increasing as the temperature range deviates from this norm. The highest mean daily CDM was recorded on days with the largest temperature range. A detailed analysis of daily mean minimum and maximum temperatures showed that both the lowest minimum as well as the highest maximum temperatures occured on these days (Table III). This highlights the importance of large short-term temperature variations on CDM. According to Fig. 2, the second highest CDM occurred on days when the difference between maximum and minimum temperatures was small (only 1 - 5°C). These days were characterised by low maximum temperatures and the relatively high CDM therefore probably reflects the negative effects of prolonged cold on susceptible individuals.

Table III. Average July temperatures (in °C) for specific daily temperature ranges (Cape Town International Airport, 1978 - 1985)

Ranges	0 - 5°C	6 - 10°C	11 - 15°C	16 - 20°C	21 - 25°C
Av. min. temp.	10,92	8,68	4,87	5,19	4,75
Av. max. temp.	14,98	16,54	17,91	21,65	26,66

Conclusions

This study has revealed a number of significant associations between CDM and temperature in Cape Town during winter. The findings are entirely consistent with those recorded elsewhere. They include: (*i*) a 2-day lag between the occurrence of extreme cold events (minimum temperature < 4°C) and CDM; (*ii*) a 2-day lag between the occurrence of extremely hot conditions (> 25°C) and CDM; and (*iii*) a strong positive link between large daily temperature fluctuations and CDM.

There is also some evidence to suggest that persistently low temperatures which last throughout the day may be associated with increased CDM.

It must, however, be stressed that the above relationships apply only to a small proportion of the total deaths from CDM. Nevertheless, these relationships do exist and in view of the importance of cardiovascular disease in South Africa, it might be prudent to give some attention to the possibility of forecasting short-term fluctuations in its incidence. Fortunately, the occurrence of extreme temperatures can usually be linked to specific synoptic conditions. For instance, in Cape Town, cold conditions which persist for some time are associated with the passage of a cold front over the area. Extremely low temperatures are most often recorded when the south Atlantic anticyclone ridges in behind the cold front, whereas the sudden onset of hot conditions during winter is always associated with berg winds, which immediately precede a coastal low pressure cell. These weather conditions are relatively easy to predict with a fair degree of accuracy and it would therefore be possible to issue early-warning weather forecasts for susceptible sectors of the population.

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