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METEOROLOGICAL CORRELATES WITH MYOCARDIAL AND CEREBRAL INFARCTION AND RESPIRATORY DISEASE

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It is well known that deaths from myocardial and cerebral infarction occur more frequently in the winter months and cold weather than in the summer (Rose, 1966; Rogot and Blackwelder, 1970; Ohno, 1969; Ohno *et al.*, 1970). The death rates from both conditions are highly correlated with air temperature but it is argued by some (Anderson and le Riche, 1970) that the association is indirect and arises because respiratory and infective disease is also commoner in cold weather and predisposes to vascular thrombosis. This paper is concerned with an exploration of this possibility and also with an examination of meteorological variables other than temperature (see Rose, 1966; Bull, 1969).

MATERIALS AND METHODS

The data are derived from the following sources. Those relating to Belfast are based on 2,348 patients suffering from myocardial infarction, 1,016 suffering from cerebrovascular accidents, 217 suffering from venous thrombosis, with or without pulmonary embolism, and 2,719 patients suffering from respiratory diseases (including 993 with pneumonia). These were admitted to a single medical unit consisting of 25 male and 25 female beds in the Royal Victoria Hospital, Belfast, and are subsets of the total patient admissions to that unit of 12,029 patients over the period 1953 to 1966 inclusive.

A second set is derived from the published returns of the Registrar General for deaths in England and Wales for 1962, 1963, and 1964 which include figures for the temperature at Kew by months.

A third set was kindly provided by Dr. P. M. Lambert of the Office of Population Censuses and Surveys and consisted of the daily deaths for 1970 from myocardial infarction and cerebrovascular disease (International Classification of Diseases, 8th Revision, 1965, Nos. 410 and 430-436 respectively) in the Greater London area, subdivided by age and sex.

The temperature data for Belfast were obtained from the meteorological station at Queen's University, Belfast through the courtesy of Professor E. Evans of the Department of Geography. Temperature and other meteorological data for each day for 1970 at Kew were kindly provided by Mr. J. T. W. Blackburn of the Meteorological Office, Bracknell.

Standard statistical techniques were used except where specified under Results.

RESULTS

GENERAL METEOROLOGICAL RELATIONSHIPS

REGISTRAR GENERAL'S DATA FOR 1962, 1963, AND 1964. Table I and Figures 1 and 2 show the very close negative correlation between air temperature and the mortality rates for myocardial infarction, cerebrovascular accidents, and respiratory disease and the weaker negative correlation with the rate for venous diseases including pulmonary embolism.

Note in Figure 1 how the mortality rates mirror the temperature and follow both minor temperature changes, as in the early months of 1962, and long-term differences between the years, the mild winter of 1963-64 being associated with the lower mortality rates.

TABLE I

CORRELATIONS BETWEEN MONTHLY MAXIMUM, MINIMUM, AND MEAN TEMPERATURES AT KEW FOR 1962, 1963, AND 1964 AND MONTHLY MORTALITY RATES IN ENGLAND AND WALES FOR MALES AND FEMALES OVER 20 YEARS OF AGE FOR MYOCARDIAL INFARCTION, CEREBROVASCULAR DISEASES, VENOUS DISEASES INCLUDING PULMONARY EMBOLISM, AND ALL RESPIRATORY DISEASES

		Max.	Min.	Mean
Myocardial infarction* (420·1)	Male	−0·85	−0·91	−0·90
	Female	−0·86	−0·91	−0·91
Cerebrovascular accidents (330-334)	Male	−0·84	−0·87	−0·88
	Female	−0·81	−0·85	−0·86
Venous diseases including pulmonary embolism (463-466)	Male	−0·58	−0·67	−0·62
	Female	−0·68	−0·74	−0·71
Total respiratory diseases (001, 002, 003, 006, 008, 470, 480, 490, 500, 510, 520)	Male	−0·80	−0·83	−0·82
	Female	−0·72	−0·75	−0·74

* (International Classification of Diseases, 1955 edition)

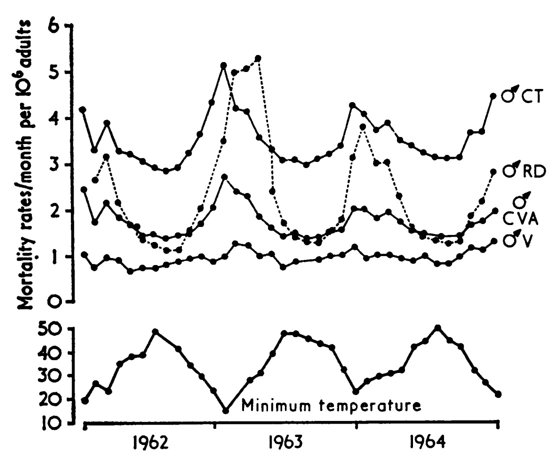

FIG. 1. Monthly mortality rates for males aged 20 and over in England and Wales for 1962, 1963, and 1964 for the diagnostic categories myocardial infarction (420·1) (CT), cerebrovascular accidents (330-334) (CVA), venous diseases including pulmonary embolism (463-466) (V), and all respiratory diseases (001, 002, 003, 006, 008, 470, 480, 490, 500, 510, 520) (RD) (International Classification of Diseases, 1955 edition) and minimum temperatures at Kew over the same period.

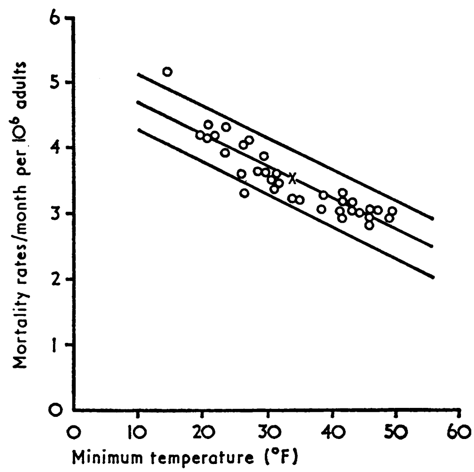

FIG. 2. Mortality rates for myocardial infarction plotted against minimum temperatures by months over the period 1962, 1963, and 1964.

BELFAST DATA Knowing the number of days in each year in which the temperature lay within given ranges and the numbers of patients admitted in that year, the expected number of admissions in each temperature range was calculated on the hypothesis that temperature and admissions were unrelated. Tables of observed values for each year were then prepared, giving the numbers of admissions in each temperature range for the day of admission: observed and expected values were summed for the total 14 years and the χ^2 values were calculated. The χ^2 values are shown in Table II together with the observed/expected ratios by age and sex. It will be seen that where the values for χ^2 are significant the O/E ratios are high at low temperatures and low at high temperatures. Thus these results show that admission rates, like deaths (from the Registrar General's 1962-64 data), are negatively related to temperature.

They reveal, in addition, an effect of age on the relationships. In the case of myocardial infarction, the effect of temperature is great in males over 55 years, barely significant in females over 55 years, and insignificant in both males and females under 55 years. In the case of cerebrovascular accidents only females show temperature dependence and this is weak and greatest in those over 55 years. In the case of pneumonia both males and females over 55 show marked temperature effects and while females under 55 show a significant effect, the younger males show no significant relationship of pneumonia to temperature.

REGISTRAR GENERAL'S DATA FOR LONDON 1970
The age relationship between death rate for myocardial infarction and strokes and temperature is further demonstrated in Table III and confirms the Belfast results. Although in the case of myocardial infarction the minimum night temperature gave the highest correlations, calculation of the coefficient of concordance (Moroney, 1951) (based on the three oldest male and two oldest female age groups) showed that the differences between the different temperatures against which the rates were correlated were not significant.

FURTHER ANALYSES OF TEMPERATURE AND OTHER METEOROLOGICAL RELATIONSHIPS

MAXIMUM/MINIMUM TEMPERATURE DIFFERENCES
In order to examine whether fluctuations in daily temperature were related to admission rates the expected number of admissions was calculated from the daily maximum and minimum temperature differences in each year and that year's total admissions (Belfast data). The observed values were then tabulated and totalled by years and the χ^2 values were calculated. The only significant values were in the oldest age groups of both males and females in the case of myocardial infarction and in females only in the case of cerebrovascular accidents. When these groups were analysed further by calculation of observed/expected ratios the results were irregular and inconsistent.

TABLE II

(*a*) VALUES FOR RATIO OBSERVED/EXPECTED ADMISSIONS WITHIN 5°F MAXIMUM TEMPERATURE RANGES FOR DAY OF ADMISSION: BELFAST ADMISSIONS 1953-66

Disease	Age and Sex	O/E Ratios Maximum Temperature °F								χ^2†	
		<40	40-44	45-49	50-54	55-59	60-64	65-69	70+	All Patients	Excluding Patients with Associated Chest Disease
Myocardial infarction	M 55+	1·19	1·30	1·06	1·02	0·91	0·84	1·00	0·72	24·1**	25·0***
	M <55	0·08	1·20	1·17	1·09	1·02	0·98	0·85	0·89	11·6	11·4
	F 55+	1·15	1·09	1·17	0·97	0·80	1·01	1·04	0·91	15·2*	13·6
	F <55	—	0·63	1·48	0·77	1·03	1·24	0·80	—	11·4	10·7
Cerebrovascular diseases	M 55+	1·07	1·29	0·88	0·97	1·20	1·02	0·70	0·49	12·9	14·1*
	M <55	—	1·13	0·73	0·86	0·96	1·19	1·21	—	6·5	5·2
	F 55+	1·05	1·36	1·33	0·85	1·08	0·76	0·76	0·95	23·9**	18·6**
	F <55	—	0·60	1·47	1·32	0·63	1·01	0·95	—	8·4	7·6
Pneumonia	M 55+	1·51	1·28	0·96	1·24	1·03	0·70	0·78	0·89	19·5**	
	M <55	0·66	1·07	1·08	0·97	1·01	0·88	1·14	1·25	4·8	
	F 55+	1·52	1·35	1·20	1·56	0·72	0·57	0·52	0·72	42·8***	
	F <55	1·17	0·86	1·29	1·24	1·26	0·78	0·39	—	13·7	
Venous thrombosis including pulmonary embolism	M + F All ages	0·74	1·30	1·11	1·11	0·88	0·97	0·68	1·17	6·2	

(*b*) VALUES FOR RATIO OBSERVED/EXPECTED ADMISSIONS WITHIN 5°F MINIMUM TEMPERATURE RANGES FOR DAY OF ADMISSION: BELFAST ADMISSIONS 1953-66

Disease	Age and Sex	O/E Ratios Minimum Temperature (°F)							χ^2†	
		<30	30-34	35-39	40-44	45-49	50-54	55+	All Patients	Excluding Patients with Associated Chest Disease
Myocardial infarction	M 55+	1·34	1·13	1·21	0·90	0·90	0·87	1·00	25·8***	26·7***
	M <55	1·34	0·83	1·13	1·00	1·07	0·90	0·86	10·7	12·2
	F 55+	1·16	1·02	1·14	0·89	0·89	1·05	1·20	8·1	9·1
	F <55	0·89	0·98	1·10	0·95	1·12	0·98	0·80	0·9	1·0
Cerebrovascular diseases	M 55+	0·76	0·99	1·13	1·13	1·07	0·89	0·42	9·8	8·2
	M <55	—	1·26	0·69	1·02	1·05	0·82	1·56	6·1	7·2
	F 55+	0·92	0·98	1·24	1·13	0·89	0·79	0·98	9·4	7·5
	F <55	—	0·97	1·11	1·02	0·82	1·09	1·27	1·7	1·3
Pneumonia	M 55+	1·82	1·05	1·10	1·20	0·95	0·67	0·57	25·0***	
	M <55	0·75	0·93	1·14	1·17	1·03	0·70	—	5·0	
	F 55+	1·76	1·32	1·18	1·28	0·76	0·55	0·65	33·1***	
	F <55	1·15	1·00	0·87	1·43	1·18	0·56	0·63	14·1	
Venous thrombosis including pulmonary embolism	M + F All ages	1·21	1·26	0·85	1·02	1·07	0·87	1·02	9·2	

*0·01<P<0·05; **0·001<P<0·01; ***P<0·001

†Degrees of freedom are one less than the number of filled columns in the part of the Table showing O/E ratios

MEDIUM-TERM TEMPERATURE SWINGS It is relevant also to enquire whether changes in temperature between days are related to admissions. This was examined by calculating the expected numbers of admissions when the temperature on the day of admission differed from that on the day before admission by given amounts. The observed values were then tabulated and χ^2 values calculated. The value was 10·627 for 7 D.F. (0·2>P>0·1) and on calculation of the observed/expected ratios no pattern emerged. In other words, rises and falls of temperature between the day before admission and the day of admission were not associated with any different pattern of admission.

OTHER METEOROLOGICAL DATA RELATED TO DEATHS FROM MYOCARDIAL INFARCTION AND STROKES

The Registrar General's (1970) data were used to calculate observed and expected deaths from

TABLE III

CORRELATION COEFFICIENTS BETWEEN DAILY DEATH RATES FROM MYOCARDIAL INFARCTION AND STROKES AND TEMPERATURE IN DIFFERENT AGE GROUPS FROM LONDON DATA FOR 1970

	Temperature	Age Group 0-44	45-54	55-64	65-74	75+
Myocardial infarction Males	Max. night	0·42	−0·72*	−0·89***	−0·86**	−0·74*
	Max. day	0·18	0·24	−0·57	−0·96***	−0·34
	Min. night	0·16	−0·41	−0·91***	−0·97***	−0·79*
	Min. day	0·61	0·02	−0·80***	−0·87***	−0·61
	No. of deaths	239	972	2,638	3,005	2,166
Females	Max. night	−0·53	−0·50	−0·72*	−0·78**	−0·85***
	Max. day	−0·58	−0·43	0·13	−0·77**	−0·88***
	Min night.	−0·62	−0·58	−0·31	−0·74*	−0·97***
	Min. day	0·50	−0·24	−0·43	−0·69*	−0·09
	No. of deaths	33	140	661	1,598	3,054
Strokes Males	Max. night	−0·63	0·14	−0·76*	0·16	−0·90**
	Max. day	−0·60	−0·21*	−0·75*	−0·64*	−0·71*
	Min. night	−0·85**	0·15	0·04	−0·65	−0·68*
	Min. day	−0·44	−0·22	−0·13	−0·63	−0·68*
	No. of deaths	70	159	519	974	1,337
Females	Max. night	0·61	−0·97	−0·81**	−0·01	−0·69*
	Max. day	0·26	−0·85**	−0·94***	−0·33	0·22
	Min. night	−0·61	−0·79*	−0·95***	−0·92***	−0·90***
	Min. day	0·39	−0·76*	−0·61	0·19	−0·88***
	No. of deaths	85	193	473	1,172	3,330

*P<0·05; **P<0·01; ***P<0·001

(The number of deaths on which the death rates were calculated is shown and where these are below 1,000 the rates and therefore the correlation coefficients are unreliable).

coronary thrombosis and strokes in relation to day and night rainfall, hours of sunshine, and wind speed. Rainfall, both by day and at night, was not significantly related in any age group but both sunshine and wind speed were significantly related to deaths in the older subjects. The significant values only are shown in Table IV. No consistent trend could be observed in the full tabulation.

The significant values for χ^2 and the significant negative correlations between hours of sunshine and deaths from myocardial infarction in older subjects are compatible with the fact that death rates are higher in winter when the hours of daylight are less.

The significant values for χ^2 for older females with myocardial infarction and older males with cerebrovascular accidents in the presence of insignificant correlations is due to the fact that excess deaths occurred at certain medium wind speeds. Calculation of observed/expected ratios revealed no particular pattern and these results are probably of no biological significance.

TABLE IV

SIGNIFICANCE OF χ^2 VALUES AND RELATED CORRELATIONS IN RESPECT OF HOURS OF SUNSHINE AND MAXIMUM WIND SPEED TO DEATH RATES FROM MYOCARDIAL INFARCTION AND CEREBROVASCULAR ACCIDENTS, PATIENTS 55 YEARS AND OVER (REGISTRAR GENERAL'S 1970 DATA)

		χ^2 Probability	r	
Myocardial infarct/hr sunshine	M	P<0·02	−0·941	P<0·01
	F	P<0·01	−0·724	P<0·05
Myocardial infarct/wind speed	F	P<0·02	+0·580	not significant
Cerebrovascular accidents/wind speed	M	P<0·01	−0·097	not significant

VASCULAR DISEASES AND POSSIBLE RELATIONSHIP TO RESPIRATORY DISEASES AND INFECTION

REGISTRAR GENERAL'S DATA (1962-64) Because mortality rates from respiratory and vascular diseases are highly correlated with temperature they are highly correlated with one another. In order to determine whether the respiratory disease death rates were influencing the rates for the other diseases partial correlations were calculated for vascular diseases, keeping the respiratory rate constant. The results are shown in Table V.

It will be seen by comparison with Table I that all the correlations were weakened by keeping the death rates for respiratory diseases constant but with the exception of the venous diseases they remained highly significant. This provides some evidence that the rates for vascular diseases are influenced by

TABLE V

PARTIAL CORRELATIONS BETWEEN MONTHLY DEATH RATES FROM VASCULAR DISEASES AND TEMPERATURE KEEPING DEATH RATES FROM RESPIRATORY DISEASES CONSTANT (REGISTRAR GENERAL'S DATA 1962, 1963, AND 1964)

		Max.	Min.	Mean
Myocardial infarction	Male	−0·54***	−0·69***	−0·67***
	Female	−0·68***	−0·78***	−0·79***
Cerebrovascular accidents	Male	−0·44**	−0·49**	−0·60***
	Female	−0·53**	−0·59**	−0·67***
Venous diseases including pulmonary embolism	Male	−0·22	−0·39*	−0·29
	Female	−0·38*	−0·48**	−0·43**

*P<0·05; **P<0·01; ***P<0·001

TABLE VI

ZERO ORDER AND PARTIAL CORRELATION COEFFICIENTS BETWEEN ADMISSION RATES FOR MYOCARDIAL INFARCTION AND PNEUMONIA AND MAXIMUM TEMPERATURE

	r	
Zero Order		
Myocardial infarction to max. temp...	−0·78	P<0·02
Pneumonia to max. temp. ..	−0·80	P<0·02
Myocardial infarction to pneumonia ..	+0·53	ns
Partials		
Myocardial infarction to max. temp. keeping pneumonia constant ..	−0·70	P<0·05
Myocardial infarction to pneumonia keeping max. temp. constant ..	−0·26	ns

ns=not significant

temperature, independent of the incidence of respiratory infections. Further evidence is shown in Figure 1.

Note in Figure 1 that there was an epidemic of respiratory deaths in the early months of 1963 and that deaths from myocardial infarction and cerebrovascular accidents fell at a time when respiratory deaths were rising. If the higher death rates from the vascular diseases were explained as being secondary to respiratory infection, one would have expected a parallel rise in deaths from the former.

BELFAST DATA Because multiple diagnoses (if they occurred) were recorded on all patients it was possible to determine the frequency of occurrence of a diagnosis of respiratory diseases in patients with myocardial infarcts and strokes and vice-versa. It was found that 11% (270/2,348) of patients with myocardial infarcts had associated chest disease. The majority of these had emphysema (common in Belfast) and only 4% (94/2,348) had pneumonia. The corresponding figures for strokes were 7% (70/1,016) and 4% (40/1,016). These percentages are so low as to make it unlikely that pneumonia preceded and caused an appreciable percentage of vascular accidents. However, this was explored further as follows.

The collected data were not arranged in such a way as to be able to determine which of the associated diseases occurred first. Although it is very unlikely that the leading event was chest diseases in all cases, the same calculations of χ^2 as were used in the rest of Table II were made on the data after removing all patients with any form of chest diseases. The results are shown in the last column of Table II for the day of admission. The effect of temperature if present remained and the χ^2 values were almost the same as those derived from the total patient data.

Table VI shows zero order and partial correlations between myocardial infarction, pneumonia, and temperature. Note that holding pneumonia constant hardly affected the correlation between myocardial infarction admission rates and temperature.

DISCUSSION

The results above confirm the earlier studies cited in the introduction which showed that the incidence of vascular accidents (cerebral and myocardial) is higher in the winter. In addition they reveal that this relationship is age-dependent and is only significant in older subjects.

The seasonal effect is most likely to be related to temperature for there is a strong negative correlation between the occurrence of vascular accidents and temperature in the older subjects. There is little to choose between night and day and maximum and minimum temperature in their associations with infarction. Swings in temperature within days and between days do not appear to be important.

Analysis of the relationship between other meteorological data and the incidence of vascular accidents showed a significant negative correlation between the hours of sunshine and death rates. This is probably simply a reflection of the fact that the days are shorter in winter. Rainfall was not significantly related but a complicated relationship between wind speed and myocardial infarction in older females and cerebrovascular accidents in older males was of doubtful biological significance.

In other studies carried out on data from various places in Europe and Japan (Arnold, 1969; Jäger, 1968; Bokonjic and Zec, 1968; Ohno, 1969 and 1970) various meteorological measurements have been shown to be significantly related to vascular accidents. However, the factors which all of these have in common is a winter association with high rates and a significant negative correlation with temperature (see also Rose, 1966).

Further analyses of the temperature relationships have been carried out and will be presented separately in another paper together with a discussion on the possible mechanisms involved.

The present study confirms that there is an association between the incidence of vascular accidents and respiratory diseases but suggests that this association is not causal; it simply arises because both are related to the weather.

SUMMARY

From an analysis of data on 2,364 patients with myocardial infarction and 1,016 patients with cerebrovascular accidents admitted to the Royal Victoria Hospital, Belfast, and from data on the same conditions recorded by the Registrar General for England and Wales for the years 1962, 1963, 1964, and 1970 the following observations were made:

1. The negative correlation between admissions and deaths from these conditions with temperature is confirmed but shown to be related to age. It is weak in subjects under the age of 55 and increases with increasing age.

2. A similar age-dependent negative correlation was shown with hours of sunshine but this probably reflects the fact that the hours of sunshine are shorter in the winter months.

3. No significant correlation could be demonstrated between the death rates for these conditions with rainfall, maximum-minimum temperature differences or differences in temperature between one day and the next.

4. Respiratory and infective diseases are also negatively correlated with temperature and season but evidence is presented which makes it unlikely that these diseases are the direct or indirect cause of the high incidence of myocardial infarction and cerebrovascular accidents in cold weather.

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