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DISAGGREGATING REGIONAL VARIATIONS IN MORTALITY BY CAUSE OF DEATH: A CASE STUDY OF THE REPUBLIC OF IRELAND

D. G. PRINGLE
Department of Geography, St Patrick's College, Maynooth, Co. Kildare, Ireland

Abstract—Significant regional disparities in life expectancy were found in a previous study of Irish mortality. An attempt is made in the present paper to assess the relative importance of each of the major causes of death to an understanding of regional disparities in total mortality, using a specially devised index known as a partial standardised mortality ratio. It is found that regional disparities created by each of the major causes of death tend to have a reinforcing effect, although cerebrovascular diseases tend to conform less closely to the patterns established by the other major causes (viz. cardiovascular diseases, malignant neoplasms and respiratory diseases). Cardiovascular diseases exert the strongest influence upon the overall pattern, but malignant neoplasms exert a much stronger influence than might be expected given the number of deaths from cancer. Regional disparities are stronger for males than for females, suggesting lines for further causal investigation.

Key words—mortality, cause of death, partial SMR, regional disparities, Ireland

Regional disparities in life expectancy and in mortality from all causes are apparent at all scales. At the global scale life expectancy varies from almost 80 years for females in Scandinavian countries to less than 40 years for males in some African countries [1]. At a continental scale major differences are often found between neighbouring countries, as reported for Western Europe by Van Poppel [2]. Within countries, disparities have been observed between regions, not only in large countries such as the United States [3] but in much smaller ones such as New Zealand [4] and the United Kingdom [5, 6]. Urban–rural differences in life expectancy have also been observed in many countries [7], whilst at an even more localised level significant disparities in mortality have been reported within individual cities [8, 9].

In the case of Ireland, statistically significant regional differences in standardised mortality rates and in the mean age at death were reported in an earlier study of deaths from all causes between 1971 and 1977 [10]. Economically prosperous counties in the south and east of the country, especially those containing the major urban areas, were generally found to have higher mortality rates and lower mean ages at death than counties in the economically more disadvantaged north and west. These findings suggest some interesting causal hypotheses, but before investigating these hypotheses it is necessary to analyse the patterns of mortality in more detail.

Different diseases can clearly have different etiologies. Consequently, if we are to explain regional disparities in total mortality, it is necessary to analyse the patterns of mortality associated with each of the major causes of death. This, however, is not as simple as it would first appear because of complications caused by *disease competition*, defined by Greenberg as a "condition in which death rates (from a particular disease) are not what would be expected from the etiological factors present in a region" [11]. Greenberg identifies three sets of circumstances likely to produce this effect: errors in recording the cause of death; a dominant etiology leading to a dominant outcome; and a dominant culture with a variety of outcomes. The existence of disease competition may cause the incidence of a particular disease to be underestimated in some areas, thereby rendering the correct identification of etiological factors more dificult. Greenberg proposes a method which may be used to explore for the existence of each of the three types of disease competition.

The approach here is slightly different. Although the complications caused by disease competition in identifying the etiological factors associated with a particular disease are recognised, the emphasis here is placed upon identifying which diseases should receive most attention if trying to explain spatial inequalities in life expectancy and mortality as a whole. This paper therefore reports the results of a study conducted to identify whether the disparities in the spatial distribution of total mortality can be attributed to regional disparities in deaths from a single disease, or whether they are the cumulative result of spatial disparities in several diseases. A second objective is to establish the extent to which the patterns of mortality from different causes are reinforcing, i.e. do areas having a high mortality rate for one type of disease also tend to have a high incidence of other types of disease? The study also considers the influence of age and sex upon the spatial distribution of mortality.

It was not felt that these questions could be fully answered using standard techniques. A number of new indices, centred upon an index referred to as a *partial standardised mortality ratio*, were therefore specially devised for the present study. These are explained in the following section.

METHODOLOGY

The likelihood of a person dying generally increases as the person gets older. Also, within each

age-group males usually have a higher death rate than females. The number of deaths in any area within a specified time period will therefore reflect, to a considerable extent, the age and sex composition of the population at risk within that area. To facilitate comparisons of the incidence of disease mortality between different areas, it is consequently usual to calculate a standardised mortality ratio (SMR) for each area.

A standardised mortality ratio may be calculated for any area i by dividing the actual number of deaths in area i, multiplied by 100, by the number which would have been expected if the death rate in each age-sex category j in area i was the same as that in the country as a whole [12]. In other words, the SMR for area i is given by the formula:

$$SMR_i = \frac{d_i}{\sum_j p_{ij} \cdot r_j} \times 100 \qquad (1)$$

where d_i is the number of deaths in area i, p_{ij} is the number of people in age-sex category j in area i, and r_j is the death rate in the country as a whole for age-sex category j. The national death rate r_j is calculated using the formula:

$$r_j = \frac{\sum_i d_{ij}}{\sum_i p_{ij}} \qquad (2)$$

In this study we wish to analyse the extent to which the spatial distribution of SMR values for all deaths reflects the spatial distribution of deaths from each of the major causes (i.e. diseases). The influence of age and sex is also of interest. The objective, in other words, may be thought of as an attempt to decompose the spatial distribution of all deaths into age, sex and cause of death components.

It is a relatively simple matter to classify the total deaths by age, sex and cause, but this does not necessarily provide an accurate indication of which elements are most important to an understanding of the *spatial* distribution of mortality. For example, a particular disease may be a major cause of death (i.e. it may account for a large percentage of the total deaths), but if it has a relatively uniform incidence throughout the country it may be relatively unimportant to an understanding of the spatial variations in total mortality.

The spatial dimension could of course be investigated using ecological correlation techniques. Coefficients of correlation could be calculated between the SMRs for total deaths and (a) age-specific death rates, (b) SMRs calculated for one sex, or (c) SMRs for a single cause of death. However, a high correlation coefficient would not necessarily indicate that the factor in question was important to an understanding of spatial disparities in the pattern of overall mortality. The spatial distribution of deaths for, say, a particular age-group could be similar to the spatial distribution of mortality as a whole, but if very few people in that age-group died then it is possible that deaths in that age-group may not be as important to an understanding of the overall pattern as deaths in another age-group which may not be as highly correlated but which account for a larger number of deaths.

The impact of a particular component (i.e. sex, age-group or cause of death) upon the spatial distribution of overall mortality is a function of both the number of deaths attributed to that component and their spatial distribution. Neither percentages nor spatial correlation techniques provide the full picture. An alternative method is therefore developed here to enable the importance of a particular component to the overall pattern to be gauged more directly.

The method proposed here is based upon the calculation of a statistic which will be referred to as a *partial standardised mortality ratio* (PSMR) because of its similarities to a partial correlation coefficient. Partial correlation techniques enable one to quantify the strength of the relationship between two variables whilst controlling for the effects of a third variable (or more). By analogy, a partial standardised mortality ratio may be defined as a standardised mortality ratio calculated after controlling for the effects of a selected component (e.g. a particular age-group or cause of death).

Let us consider the situation where we wish to calculate a partial standardised mortality ratio controlling for the effects of deaths in a particular age-group. A standardised mortality ratio is calculated by dividing the number of deaths in an area by the number which would be expected given its age composition. High SMR values (i.e. values larger than 100) arise if the number of deaths is greater than expected, whereas low SMR values (i.e. values less than 100) arise if the number of deaths is less than expected. The total number of deaths in an area, however, is the sum of the deaths in each age category. The numerator in formula (1), in other words, can be rewritten as:

$$d_i = \sum_j d_{ij} \qquad (3)$$

where d_{ij} is the number of deaths in age category j in area i. The extent to which an SMR value deviates from 100 is a reflection of the cumulative extent to which the components d_{ij} vary from their expected values. The impact of spatial variations in mortality within age category j upon the values of the SMRs can therefore be controlled for (or statistically eliminated) by replacing the actual numbers of deaths in category j in each area by the numbers which would be expected if the death rate for that age category was the same in all areas. The partial SMR, controlling for variations in age-group a, can therefore be written as follows;

$$PSMR_{i \cdot a} = \frac{\sum_j d_{ij} - d_{ia} - p_{ia} \cdot r_j}{\sum_j p_{ij} \cdot r_j} \qquad (4)$$

The partial SMR, controlling for variations in a cause of death c, can similarly be written as:

$$PSMR_{i \cdot c} = \frac{\sum_k d_{ik} - d_{ic} + \sum_j p_{ij} \cdot r_{jc}}{> p_{ij} \cdot r_j} \qquad (5)$$

where d_{ik} is the number of deaths in area i due to

cause of death k, and r_{jc} is the national death rate within age-group j for the control cause of death c.

Partial SMRs can be calculated for each area using formula (4) or (5) as appropriate. The partial SMR value for each area indicates the value which the SMR value would have had if the number of deaths in the control group was directly proportional to the number of people at risk in the control group (i.e. if there were no spatial variations in the death rate for the control group). The impact of spatial variations in the death rate within the control group upon the total SMR can therefore be easily quantified for each area by subtraction. This quantity, which will be referred to as the *component deviation* Δ, is defined for each area i as

$$\Delta_i = \mathrm{SMR}_i - \mathrm{PSMR}_i \qquad (6)$$

where PSMR_i is the partial SMR in area i controlling for the component in question. The component deviation will have a positive value if the effect of deaths in the control group is to increase the value of the overall SMR in that area, and a negative value if there are fewer deaths in the control group than would be expected thereby lowering the value of the overall SMR. If partial SMRs are calculated for all possible control groups of a particular type (i.e. every cause of death or every age-group), the sum of the corresponding component deviations in a given area will be equal to the total deviation of the overall SMR from 100.

The component deviations enable one to assess the impact of a selected component upon the SMR for all deaths in a particular area. It is also useful to have a measure of the importance of the selected component to an understanding of the distribution of the SMRs in all areas. A third statistic, referred to as the *proportional reduction in variance* (PRV) is defined for this purpose. Each component usually makes a positive contribution to the variance of the SMRs for all deaths, i.e. when the component is controlled for by calculating a partial SMR, the partial SMR values are generally lower than the corresponding non-partial (or full) SMRs in areas with a high SMR value, and higher than the full SMR values in areas with a low SMR. The partial SMRs, in other words, generally have a lower variance than the full SMRs. The relative importance of the contribution of a selected control group to the variance of the full SMRs can consequently be quantified by calculating the percentage reduction in variance achieved by standardising for that particular control group. This may be defined as

$$\mathrm{PRV} = \frac{\mathrm{Var(SMR)} - \mathrm{Var(PSMR)}}{\mathrm{Var(SMR)}} \times 100 \qquad (7)$$

where Var(SMR) is the variance of the full SMR values, and Var(PSMR) is the variance of the partial SMRs.

THE DATA

The mortality data used in this study were extracted from the Report On Vital Statistics which is compiled each year for the Minister of Health by the Central Statistics Office [13]. Table 24 in this report gives the number of deaths, disaggregated by 10 year age-groups and sex, attributed to each of the major causes of death in each County and County Borough—a total of 32 areas, ranging in population from 28,250 (County Longford) to 567,866 (Dublin County Borough; Fig. 1). Most areas, however, have a population of between 50,000 and 75,000. The numbers in some cells of Table 24 are very small, therefore data were extracted for 11 consecutive years (1971–1981 inclusive) to minimise the possibility of spurious results arising from small numbers. The study reported here is based upon an analysis of the total number of deaths in each category between 1971 and 1981.

Fig. 1. Location of counties and county boroughs.

Data on the age-sex composition of the populations at risk were extracted from the 1971 and 1981 censuses [14]. Significant increases in population occurred in many areas during the study period, resulting in an increase in total population from 2,978,000 in 1971 to 3,443,000 in 1981. To simplify matters, the rate of increase is assumed to have been uniform over time and the means of the 1971 and 1981 values for each cell were therefore used as estimates of the population at risk for the 11 year study period as a whole. Although the assumption of a uniform rate of population increase is probably unrealistic, it is not believed to cause a serious bias in the present analysis which is based upon comparisons between counties.

SEX AND MORTALITY

As in many countries, significant disparities in mortality and life expectancy exist in Ireland between males and females. Males accounted for 54.6% of all deaths in the period 1971–1981, whereas they comprised only 50.2% of the total population in 1981. This discrepancy arises from the fact that male births outnumber female births (51.4:48.6%), but males on

Table 1. The number and percentage of deaths in each age category for males and females, 1971–1981

Age category	Males	Females
0–4	7938 (3.9%)	5966 (3.5%)
5–14	1484 (0.7%)	836 (0.5%)
15–24	3165 (1.6%)	1180 (0.7%)
25–34	2684 (1.3%)	1310 (0.7%)
35–44	4369 (2.2%)	2659 (1.6%)
45–54	12,532 (6.2%)	7883 (4.7%)
55–64	31,694 (15.7%)	18,463 (11.0%)
65–74	57,665 (28.6%)	38,703 (23.0%)
>75	80,443 (39.8%)	91,226 (54.2%)

Table 2. Correlations between SMRs for each sex

	Total	Males	Females
Total	1.00		
Males	0.95	1.00	
Females	0.91	0.73	1.00

average have a shorter life span. Male life expectancy at birth in 1970–72, according to Irish Life Table No. 8, was 68.8 years, whereas female life expectancy was 73.5 years [13, Appendix, 1974]. This was reflected by males having a higher percentage of deaths in every age category below the age of 75 between 1971 and 1981 (Table 1). More than 50% of women lived to the age of 75 or more, whereas the corresponding percentage for males was almost 15% lower.

To facilitate comparisons between areas, whilst controlling for age variations, standardised mortality ratios were calculated for all deaths and also for males and females separately. The correlations between the three sets of SMRs are shown in Table 2.

The SMRs for all deaths are, as one would expect, very highly correlated with the SMRs for each of the two component sexes. The correlation between the SMRs for males and females is much lower ($r = 0.73$), but is statistically highly significant indicating that the mortality patterns for both sexes are broadly similar. Nevertheless, visual comparison of the spatial distributions of the two sets of SMRs reveals a number of interesting, and possibly causally significant, differences. Males and females are consequently analysed separately in the remainder of this study.

AGE AND MORTALITY

In order to establish whether the patterns of mortality in each age-group tend to reinforce one another, or whether the net pattern is the resolution of unevenly balanced and contradictory tendencies, the death rate within each age category was calculated for each area. The degree of correspondence in the spatial distribution of the resulting age-specific mortality rates was then examined for each sex by correlation analysis (Table 3).

High correlations are found between the age specific mortality rates for males in the older age-groups. The spatial distributions of mortality in the 55–64 and 65–74 age-groups, for example, are highly correlated with one another and also, to a lesser extent, with the deaths in the 0–4, 45–54 and 75 plus age-groups. Deaths in the other age-groups record much lower correlation coefficients, not only with these age-groups but also amongst themselves.

The situation, however, is much more complex for females. Although the highest correlations are again found between the older age-groups, the correlation coefficients tend to be much lower than for males. Also, compared with males, the pattern of female deaths in the over 75 age category is very weakly correlated with most of the other age-groups. The spatial distribution of total female mortality would therefore appear to be the product of contradictory tendencies to a much greater extent than that for males.

It is clear from Table 1 that the number of deaths increases rapidly with increasing age. Given that there are more deaths in the older age-groups, one might expect the spatial distributions of deaths in the older age-groups to exert a stronger influence upon the distribution of SMRs for each sex than deaths in the younger age-groups. This hypothesis was tested by calculating partial SMRs controlling for each age-group in turn. The relative importance of the contribution of each age category to the full SMRs was then quantified by calculating the percentage reduction in variance for each set of partial SMRs (Table 4).

The PRV results confirm that deaths in the older age categories have much more impact upon the patterns of total mortality than deaths in the younger age-groups. The variance of the SMRs for males, for example, would be reduced by almost 60% if the death rate in the 65–74 year old age-group was the same in all areas. The elimination of regional disparities in the death rate for males in the 15–24 year old age-group, on the other hand, would result in virtually no change at all in the distribution of the SMRs.

The PRV values conform to a similar pattern for both sexes. Following moderately high values for the 0–4 year old category, very low PRV values are

Table 3. Correlations between age specific mortality rates

	Age group								
	0–4	5–14	15–24	25–34	35–44	45–54	55–64	65–74	>75
0–4	1.00	−0.11	0.15	−0.06	0.48	0.45	0.47	0.34	0.02
5–14	0.18	1.00	0.27	−0.04	−0.42	0.04	0.42	0.27	0.21
15–24	0.04	0.08	1.00	−0.17	0.06	0.05	0.32	0.29	0.18
25–34	0.13	0.05	0.41	1.00	0.14	0.02	−0.09	−0.11	0.17
35–44	0.18	0.00	0.20	0.28	1.00	0.37	0.32	0.25	0.08
45–54	0.54	0.16	−0.10	−0.03	0.54	1.00	0.66	0.65	0.20
55–64	0.60	0.30	−0.11	−0.04	0.45	0.81	1.00	0.79	0.08
65–74	0.48	0.25	−0.13	−0.14	0.50	0.89	0.91	1.00	0.43
>75	0.35	0.11	0.01	−0.10	0.48	0.60	0.65	0.66	1.00

Correlations for females are above the principal diagonal, and those for males are below it.

Table 4. Percentage reduction in the variance of SMRs controlling for each age category

Control group	Males	Females
0–4	9.16	10.47
5–14	0.83	1.41
15–24	0.43	2.02
25–34	1.32	1.32
35–44	6.86	4.74
45–54	19.70	13.13
55–64	37.16	20.18
65–74	59.17	46.25
>75	34.26	52.73

recorded for childhood and young adult age categories. However, the PRV values increase rapidly from about the age of 40 onwards. This increase continues into the oldest age category in the case of females, but there is an inversion in the trend for males. In other words, deaths occurring after the age of 75 are the most important component determining the net pattern of mortality for females, whereas deaths in the slightly younger 65–74 age-group provide the single most important component of male mortality.

The pattern of deaths in the over 75 age category is clearly important to an understanding of the spatial distribution of mortality as a whole, especially in the case of females where deaths in the over 75 age category not only provide the largest PRV value but comprise more than half of all female deaths. However, deaths in the over 75 age category are more difficult to interpret than deaths in the other age categories, due to the fact that everyone eventually dies sometime. A higher than average number of deaths in the over 75 age category in an area might indicate that the area is disadvantaged in the sense that old people in that area have a greater risk of death than old people in other areas, but it could also indicate that the area is advantaged if the high death rate amongst the elderly reflects the eventual deaths of the 'survivors' in an area characterised by a low death rate in the younger age-groups. The inclusion of deaths in the over 75 age-group in the calculation of the SMRs may therefore disguise important regional disparities in health if a 'residual' effect of this type is present.

The fact that the pattern of age-specific mortality rates in the 75 plus age category for females is only weakly correlated with the patterns of mortality in the other age categories would tend to suggest that residual effects are indeed present in this study. These suspicions are reinforced by a recalculation of the standardised mortality ratios, using only deaths under the age of 75, because the recalculated SMRs are found to have a much higher variance. In the case of males the variance is increased from 66.9 to 111.4, whereas for females it is increased from 35.5 to 72.2. These results, coupled with the high PRV values for the over 75 age categories for both sexes, suggest that the inclusion of the deaths in the over 75 age category may create an important 'noise' factor which disguises regional disparities in mortality. Deaths in the over 75 age category are therefore omitted from consideration in the remainder of the analysis.

Table 5. Percentage reduction in the variance of SMRs calculated using only deaths under the age of 75

Control group	Males	Females
0–4	11.28	18.08
5–14	1.09	1.75
15–24	0.14	2.48
25–34	1.14	0.50
35–44	7.32	7.14
45–54	24.34	21.53
55–64	45.85	40.52
65–74	71.22	68.08

The omission of the 75 plus age category in the calculation of the SMRs alters the total variance, and consequently the percentage reduction in variance which can be achieved by controlling for each of the remaining age categories, but the relative importance of each age category remains much the same (Table 5).

CAUSE OF DEATH

The number of deaths in each age-group attributed to each of the principal causes of death is given in Table 6. The four major disease categories (i.e. malignant neoplasms, heart diseases, cerebrovascular disease and diseases of the respiratory system) together account for over three quarters of the total deaths for both males and females. Indeed, the percentage of deaths attributed to each of these causes is very similar for both sexes. Males have a higher percentage of heart diseases, but a correspondingly lower percentage of cerebrovascular diseases (i.e. the percentage of deaths attributed to diseases of the circulatory system as a whole is more or less the same for each sex). The higher incidence of cerebrovascular disease for females makes it the third most important cause of death for females, whereas it is the fourth most important cause of death for males after respiratory diseases. Heart diseases and malignant neoplasms are the first and second most important causes of death for both sexes.

The relative importance of a particular cause of death to an understanding of the spatial distribution of mortality as a whole need not necessarily be a direct function of the number of deaths which it causes. A disease which is the cause of a large number of deaths will, all other things being equal, be important to an understanding of the spatial distribution of mortality as a whole but, as noted above, its importance will be modified by the nature of its spatial distribution. The relative importance of each disease to an understanding of the overall spatial distribution is therefore assessed by calculating partial standardised mortality ratios, controlling for each disease in turn. The resulting percentage reductions in the variance of the SMRs for deaths under the age of 75 are presented in Table 7.

The rank order of the PRV values for males, with the exception of the 'other' category, is the same as that for the percentage of deaths caused by each disease. Heart diseases have the largest PRV value, followed by malignant neoplasms, respiratory diseases, other causes and cerebrovascular diseases. However, malignant neoplasms have almost as large a PRV value as heart diseases although they account

Table 6(a). Numbers and percentages of deaths in each age-group by cause of death for males

	Malignant neoplasms	Heart diseases	Cerebrovascular diseases	Respiratory diseases	Other causes
0–4	154 (1.9)	6 (—)	5 (—)	1233 (15.5)	6540 (82.4)
5–14	204 (13.7)	13 (0.8)	24 (1.6)	98 (6.6)	1145 (77.2)
15–24	252 (8.0)	71 (2.2	86 (2.7)	150 (4.7)	2606 (82.3)
25–34	394 (14.7)	208 (7.7)	101 (3.8)	133 (5.0)	1848 (68.9)
35–44	883 (20.2)	1182 (27.1)	249 (5.7)	229 (5.2)	1826 (41.7)
45–54	2967 (23.7)	4925 (39.3)	777 (6.2)	980 (7.8)	2883 (23.0)
55–64	7893 (24.9)	12,750 (40.2)	2399 (7.6)	3303 (10.4)	5347 (16.9)
65–74	12,778 (22.2)	21,720 (37.7)	6181 (10.7)	7845 (13.6)	9141 (15.8)
>75	10,901 (13.6)	28,792 (35.8)	11,790 (14.7)	13,263 (16.5)	15,697 (19.5)
Total	36,426 (18.0)	69,667 (34.5)	21,612 (10.7)	27,234 (13.5)	46,937 (23.2)

Figures in parentheses indicate percentage of deaths within each age group attributed to each cause of death.

Table 6(b). Numbers and percentages of deaths in each age-group by cause of death for females

	Malignant neoplasms	Heart diseases	Cerebrovascular diseases	Respiratory diseases	Other causes
0–4	101 (1.7)	10 (0.2)	13 (0.2)	864 (14.5)	4978 (83.4
5–14	151 (18.0)	9 (1.1)	22 (2.6)	73 (8.7)	581 (69.5)
15–24	171 (14.5)	28 (2.4)	59 (5.0)	94 (8.0)	828 (70.2)
25–34	343 (26.2)	77 (5.9)	80 (6.1)	107 (8.2)	703 (53.7)
35–44	1113 (41.9)	287 (10.8)	223 (8.4)	196 (7.4)	840 (31.6)
45–54	3403 (43.2)	1439 (18.3)	793 (10.1)	624 (7.9)	1624 (20.6)
55–64	6406 (34.7)	4826 (26.1)	2048 (11.1)	1824 (9.9)	3359 (18.2)
65–74	8991 (23.2)	12,026 (31.1)	6068 (15.7)	4355 (11.3)	7263 (18.8)
>75	9705 (10.6)	30,770 (33.7)	17,958 (19.7)	12,551 (13.8)	20,242 (22.2)
Total	30,384 (18,1)	49,472 (29.4)	27,264 (16.2)	20,688 (12.3)	40,418 (24.0)

Figures in parentheses indicate percentage of deaths within each age group attributed to each cause of death.

for only slightly more than half as many deaths. This is because the incidence of malignant neoplasms is characterised by a greater degree of spatial inequality, consequently deaths from malignant neoplasms exert a greater influence upon the overall distribution of mortality than their absolute numbers would lead one to expect. Respiratory diseases exert a moderately important influence, whereas cerebrovascular diseases are relatively unimportant to an understanding of the overall pattern.

The rank ordering of the PRV values for females also corresponds fairly closely to the rank order of the percentage of deaths caused by each disease. The major exception is cerebrovascular diseases which, although the third most important cause of female deaths, has a fairly low PRV value. This is because deaths from cerebrovascular disease, although quite numerous, have a fairly uniform spatial distribution. The PRV values for heart diseases, malignant neoplasms and respiratory diseases are lower than the corresponding values for males, reflecting a more uniform spatial distribution of deaths from these diseases for females (i.e. disparities in the male patterns are more strongly developed).

Having identified the most important components of the patterns of total mortality, we now wish to establish whether their effects are complementary or contradictory. This question was examined by calculating the component deviations for each of the 32 areas. The results are given in Tables 8 and 9 and are summarised in Figs 2 and 3. In each instance, arbitrary values were selected to enable the overall SMR values to be classified as 'high,' 'medium' or 'low' and the component deviations to be classified as 'large' or 'small.' Counties having an overall SMR value greater than 105 were classified as high mortality areas, whilst counties with an SMR value less than 95 were classified as low mortality areas. Likewise, the component deviation for a disease was classified as 'large' if it had an absolute value of 2 or more. The component deviations can be either positive or negative. If controlling for a disease by calculating a partial standardised mortality ratio resulted in a lower value than the full SMR, the component deviation is positive (i.e. it indicates that the disease in question is making a positive contribution to the overall SMR value in that area). Figures 2 and 3 show the locations of large positive and negative component deviations superimposed upon a map of the high, medium and low mortality areas for males and females respectively.

Table 7. Percentage reduction in the variance of SMRs controlling for each of the major causes of death

Disease controlled for	Males	Females
Malignant neoplasms	48.88	30.82
Heart diseases	51.36	43.46
Cerebrovascular disease	12.64	21.34
Respiratory diseases	29.72	26.38
Other causes	20.78	34.96

Using the criteria noted above, about half the component deviations are classified as 'large.' Cancer and heart diseases, however, having the largest PRV values, contribute more large deviations than either of the other two diseases.

The high mortality areas generally have large positive component deviations for at least two diseases, although there are a few exceptions. Limerick County, for example, is a high mortality area for males mainly due to a very high incidence of heart disease, whilst Carlow, Dublin County Borough (i.e. city) and Westmeath are high mortality areas for females mainly because of a high incidence cerebrovascular disease, malignant neoplasms and respiratory diseases respectively.

Table 8. Component deviations for males

	SMR	Component deviations				
		Malignant neoplasms	Heart diseases	Stroke	Respiratory diseases	Other causes
Carlow	108.82	0.87	2.74	2.51	1.41	1.27
Dublin C.B.	116.63	8.04	4.10	−1.17	3.27	2.38
Dun Laoghaire	116.58	6.46	4.89	0.51	1.24	3.46
Dublin Co.	79.59	−1.57	−5.07	−2.55	−2.39	−8.81
Kildare	108.17	0.72	2.12	2.02	2.14	1.16
Kilkenny	97.06	−1.12	−0.42	0.83	−1.12	−1.10
Laois	95.23	−2.45	1.03	−0.21	−0.56	−2.56
Longford	105.80	−1.16	3.77	4.84	0.54	−2.20
Louth	112.37	3.84	2.98	1.33	1.86	2.34
Meath	99.79	0.46	−1.03	−0.42	0.19	0.59
Offaly	90.67	−3.03	−4.14	0.43	−1.30	−1.27
Westmeath	98.03	−2.67	0.88	−1.19	2.57	−1.56
Wexford	99.59	−0.15	1.59	0.28	−0.57	−1.55
Wicklow	100.15	0.02	0.09	1.15	−0.74	=0.37
Clare	95.31	−3.74	1.08	−0.19	−1.07	−0.75
Cork C.B.	120.85	7.01	6.34	0.75	3.70	3.03
Cork Co.	100.35	−0.53	−1.21	−0.02	−0.96	3.09
Kerry	96.98	−3.27	0.47	0.09	−1.23	0.91
Limerick C.B.	122.90	4.42	8.92	2.48	3.19	3.86
Limerick Co.	105.33	−1.38	4.67	0.11	0.64	1.27
Tipperary N.R.	99.47	0.06	1.89	1.28	−1.72	−2.04
Tipperary S.R.	104.44	−0.21	2.65	3.61	1.02	−2.63
Waterford C.B.	114.00	6.84	3.10	3.11	5.59	−4.65
Waterford Co.	95.87	−1.88	−2.76	1.87	1.12	−2.48
Galway	84.75	−4.91	−5.03	−2.29	−2.71	−0.27
Leitrim	95.05	−2.65	−3.86	0.55	0.32	0.69
Mayo	82.60	−5.13	−7.84	0.12	−3.14	−1.39
Roscommon	88.27	−5.23	−3.31	1.16	−2.79	−1.54
Sligo	93.70	−2.80	−4.64	0.42	−0.94	1.68
Cavan	99.42	−3.25	−1.83	1.99	−0.13	2.65
Donegal	88.20	−5.09	−3.66	−0.88	−2.32	0.16
Monaghan	95.76	−3.21	1.89	−0.85	−0.76	−1.38

Table 9. Component deviations for females

	SMR	Component deviations				
		Malignant neoplasms	Heart diseases	Stroke	Respiratory diseases	Other causes
Carlow	116.04	0.37	1.91	6.10	1.00	6.63
Dublin C.B.	106.25	3.65	0.53	−1.42	1.73	1.74
Dun Laoghaire	100.39	3.08	−1.18	−1.81	−1.64	1.95
Dublin Co.	78.69	−3.70	−5.05	−2.33	−2.40	−7.81
Kildare	114.95	0.96	5.43	2.87	2.53	3.13
Kilkenny	98.38	−1.63	0.02	0.90	−1.30	0.39
Laois	98.43	−0.03	−1.93	0.76	0.92	−1.28
Longford	102.33	−2.11	2.32	5.31	−0.93	−2.25
Louth	108.17	2.68	2.47	1.32	0.25	1.43
Meath	102.42	0.23	−0.42	4.38	1.40	−3.17
Offaly	97.18	0.75	−3.53	1.06	−0.02	−1.07
Westmeath	107.75	−0.27	1.54	1.39	3.25	1.82
Wexford	104.54	0.83	2.80	0.43	0.34	0.12
Wicklow	103.53	2.28	0.43	1.36	0.45	−1.01
Clare	97.77	−3.53	0.26	1.51	−0.05	−0.40
Cork C.B.	112.09	3.47	4.32	−0.45	1.67	3.06
Cork Co.	101.52	0.19	−1.72	0.43	−1.08	3.70
Kerry	98.03	−2.50	−0.24	0.18	−0.50	1.11
Limerick C.B.	119.34	1.95	8.19	1.54	3.05	4.59
Limerick Co.	100.65	−1.55	3.46	−0.22	−1.08	0.05
Tipperary N.R.	104.45	0.16	2.58	2.54	−2.02	1.18
Tipperary S.R.	104.01	−0.07	2.77	2.70	1.55	−2.93
Waterford C.B.	108.27	2.83	1.56	0.36	5.65	−2.14
Waterford Co.	97.42	0.91	−5.75	0.36	2.65	−0.75
Galway	85.08	−4.60	−3.88	−2.61	−2.61	−1.20
Leitrim	99.28	0.41	−1.72	0.68	2.65	−2.74
Mayo	84.91	−4.38	−3.76	−1.23	−3.19	−2.50
Roscommon	93.15	−4.19−	0.50	0.31	−3.25	−0.21
Sligo	96.33	0.46	−1.58	−1.86	−0.38	−0.29
Cavan	100.55	−0.85	−0.77	3.77	0.00	−1.59
Donegal	93.82	−1.87	0.09	−1.47	−1.19	−1.72
Monaghan	102.67	−2.27	6.55	1.76	−0.39	−2.97

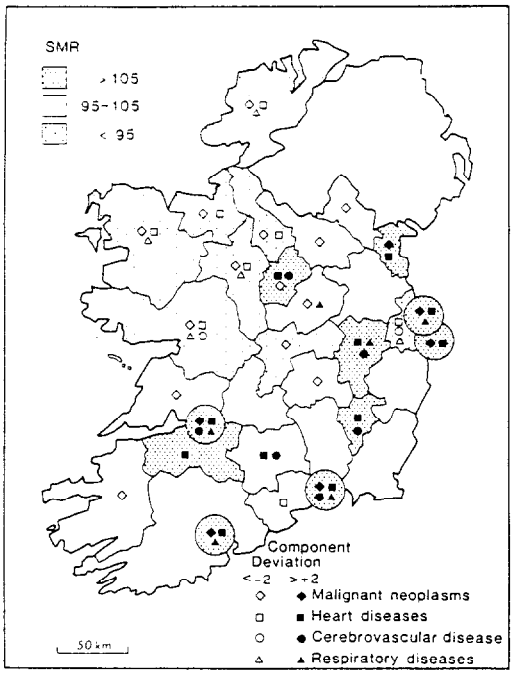

Fig. 2. Standardised mortality ratios and component deviations for males.

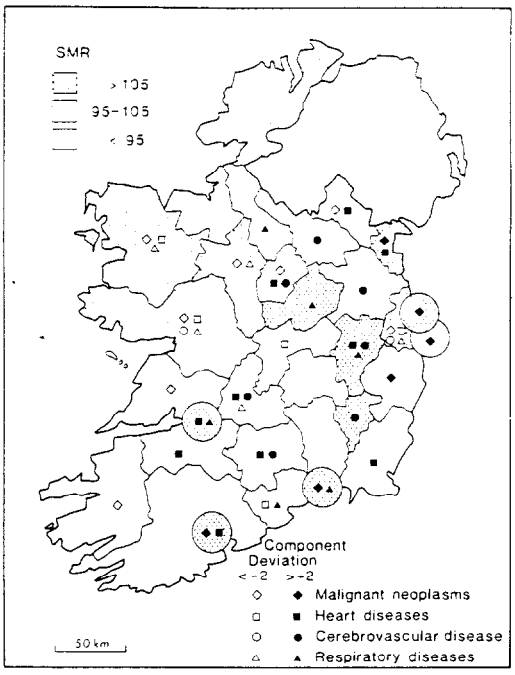

Fig. 3. Standardised mortality ratios and component deviations for females.

Similarly, low mortality areas, with only one exception, each have large negative component deviations for at least two diseases. The exception is Donegal for females. Donegal does not have a large female component deviation for any disease, but it has medium sized negative deviations for malignant neoplasms, cerebrovascular disease and respiratory diseases which reinforce one another to give Donegal the fourth lowest level of female mortality overall.

Many medium mortality areas do not have any large component deviations. In other words, they have an overall mortality rate close to the national average simply because their incidence for each of the major diseases is close to the national average. Most of the other medium mortality areas only have one large component deviation. The effect of this large component deviation in most instances is to pull the overall mortality rate up to the upper end of the medium mortality range if the component deviation is positive, or down to the lower end of the medium mortality range if the deviation is negative. Most of these 'maverick' large deviations for males are negative deviations for malignant neoplasms (e.g. Cavan, Clare, Kerry, Laois and Monaghan), but the deviations for females arise from a greater variety of diseases and are more often positive.

Few medium mortality areas have two or more large component deviations. In most instances (i.e. Westmeath for males, and Longford, Monaghan, Tipperary North, and Waterford County for females) the high incidence of one disease is counteracted by a low incidence of another to produce a medium overall mortality. Tipperary South provides a curious exception due to the fact that it has a high incidence of both heart diseases and cerebrovascular diseases for males and females, but the incidence is not sufficiently high in either case to push the county into the high mortality category overall despite the absence of any large negative deviations to compensate.

With the exception of a few areas which have large deviations of opposite signs, the general impression is that the spatial distributions of each of the major causes tend to have a reinforcing effect. This impression is supported, especially in the case of males, by an examination of the correlation coefficients between the SMRs for each of the major causes of death (Table 10).

The SMRs for malignant neoplasms, heart diseases and respiratory diseases for males are strongly intercorrelated, whilst the correlations between these diseases and cerebrovascular diseases, although not as strong, are also positive. The correlations for females, although all positive, are generally weaker and would appear to identify two clusters. Malignant neoplasms

Table 10. Correlations between SMRs for different causes of death

	Malignant neoplasms	Heart diseases	Cerebrovascular	Respiratory diseases	Other causes
Malignant neoplasms	1.00	0.31	0.12	0.65	0.45
Heart diseases	0.73	1.00	0.42	0.34	0.44
Cerebrovascular disease	0.29	0.45	1.00	0.30	0.21
Respiratory diseases	0.81	0.73	0.44	1.00	0.20
Other causes	0.33	0.37	0.06	0.26	1.00

Correlations for females are above the principal diagonal, and those for males are below it.

and respiratory diseases are strongly correlated, but both (in contrast to males) are only weakly correlated with heart diseases. Heart diseases in turn are fairly strongly correlated with cerebrovascular diseases.

The absence of any negative correlation coefficients suggests that 'residual effects' are relatively unimportant. In other words, the high incidence of a disease in a given area would seem to indicate the probable existence of possible causal factors in that area rather than indicating that the area has a high incidence of the disease in question because it has a low incidence of other diseases. This interpretation is supported by a detailed examination of the component deviations.

SUMMARY AND DISCUSSION

Regional disparities in the spatial distribution of deaths from all causes are not the product of disparities in the pattern of deaths in a single age-group or from a single cause of death. Rather, the overall pattern would appear to be the product of broadly reinforcing patterns of mortality within most age-groups and from most of the major causes of death. However, the pattern of deaths in the over 75 age category is sufficiently different to suggest the possible existence of a residual effect caused by a high death rate in some areas amongst those who survived to an old age because of a low death rate in the younger age categories.

Although deaths in different age-groups and from each of the major causes of death tend to reinforce the overall pattern of mortality, deaths in the older age-groups below 75 and from heart diseases (for both sexes) and malignant neoplasms (for males) have a greater influence upon the overall pattern than deaths in the other categories. The influence of a particular category (i.e. age-group or cause of death) upon the overall pattern generally tends to be a function of the number of deaths occurring within that category, but the partial standardised mortality ratios indicate that the spatial distribution of the deaths in that category is also an important factor. Cerebrovascular diseases, for example, are less important to an understanding of the spatial distribution of overall female mortality than the number of deaths from cerebrovascular disease might suggest, whereas malignant neoplasms exert a much greater influence upon the pattern of overall male mortality than the number of deaths from cancer might suggest.

The distribution of mortality for females is broadly similar to that for males, but the disparities are more pronounced for males. The variance of the SMRs for all male deaths, for example, is much larger than the variance of the SMRs for all female deaths. This reflects a higher degree of variance in the SMRs for each of the major causes of death for males, coupled with a higher degree of correlation between their spatial distributions. Most areas having either a large positive component deviation or a large negative component deviation for one cause of death for males usually have large component deviations of the same sign for other causes of death, whereas for females there is a larger number of areas having only one large component deviation or else two or more deviations with conflicting signs.

Table 11. Correlations between urbanisation and SMRs for each of the major causes of death

	Males	Females
All causes	0.62	0.34
Malignant neoplasms	0.84	0.58
Heart diseases	0.52	0.22
Cerebrovascular disease	0.00	−0.27
Respiratory diseases	0.62	0.34
Other causes	0.12	0.29

It is not possible to determine with certainty the presence or absence of disease competition using the present methods, but the fact that the patterns of mortality from each of the major diseases are reinforcing, especially for males, suggests the possible presence of a dominant culture-variety of outcomes type of disease competition, whilst the 'idiosyncratic' nature of the pattern of deaths amongst the over 75s might indicate the presence of a dominant etiology-dominant outcome type of disease competition. A more detailed analysis, using a more disaggregated classification of causes of death, would be required to test these hypotheses. This, however, would increase the likelihood of spurious results due to the error type of disease competition. Although errors are not believed to seriously distort the results at the level of disaggregation examined in the present analysis, concern has been expressed elsewhere about the accuracy of death certification [15, 16] and the degree of non-registration in Ireland [17, 18].

The present study was not designed to test causal hypotheses, but is should perhaps be noted that the findings reported here suggest that the disparities in Irish mortality appear to be related to urbanisation. The highest incidence of most causes of death are in the major urban areas, whilst the counties in the south and east are more urbanised and generally experience higher mortality rates for most causes of death than counties in the north and west. The correlations between the percentage of people living in urban areas and the SMRs for each of the major causes of death provide statistical support for this interpretation (Table 11). Within the major urban areas there would appear to be a significant correlation between social class and mortality from most types of cancer, cardiovascular diseases and respiratory diseases [19, 20].

The nature of the relationships between mortality, urbanisation and social class is to be the subject of further research.

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