# Epidemiology

## INFANT MORTALITY, CHILDHOOD NUTRITION, AND ISCHAEMIC HEART DISEASE IN ENGLAND AND WALES

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***Summary*** Although the rise in ischaemic heart disease in England and Wales has been associated with increasing prosperity, mortality rates are highest in the least affluent areas. On division of the country into two hundred and twelve local authority areas a strong geographical relation was found between ischaemic heart disease mortality rates in 1968–78 and infant mortality in 1921–25. Of the twenty-four other common causes of death only bronchitis, stomach cancer, and rheumatic heart disease were similarly related to infant mortality. These diseases are associated with poor living conditions and mortality from them is declining. Ischaemic heart disease is strongly correlated with both neonatal and postneonatal mortality. It is suggested that poor nutrition in early life increases susceptibility to the effects of an affluent diet.

### INTRODUCTION

IN England and Wales, death rates during the past hundred years have been consistently higher in the north and west of the country than in the south and east.[1] Formerly this reflected differences in the incidences of infective diseases that were attributable to inequalities of living standards. Today it reflects differences in mortality from chronic diseases, most importantly ischaemic heart disease. It is a paradox that although the steep increase in ischaemic heart disease during this century[2,3] has been associated with rising prosperity, the disease is now more common in poorer areas[4] and lower-income groups.[5]

We have explored the association between poor living standards and ischaemic heart disease by a detailed geographical comparison of infant mortality between 1921 and 1925 and death in adults from ischaemic heart disease and other leading causes between 1968 and 1978.

### METHODS

The Office of Population Censuses and Surveys made available to us extracts from all death certificates in England and Wales during 1968–78. There were twenty-five causes of death, as coded under the eighth revision of the international classification of diseases (ICD), for which more than 10 000 deaths occurred in each sex, or in the sex usually affected. These were: cancers at twelve sites, (oesophagus, stomach, colon, rectum, pancreas, lung, breast, cervix, uterus, ovary, prostate, and bladder); ischaemic heart disease; rheumatic heart disease; subarachnoid haemorrhage; stroke; diabetes; prostatic hyperplasia; traffic accidents; falls; aortic aneurysm; pulmonary embolism; pneumococcal pneumonia; bronchitis; and suicide.[6,7] Mortality rates for each sex for each local authority area were calculated from 1971 Census data, which we grouped according to pre-1974 local authority boundaries. Death rates were expressed as standardised mortality ratios (SMRs).

We have compared adult mortality (1968–78) with infant mortality in the four main geographical groups used by the Registrar General since 1911,[1]—ie, county boroughs (CBs, larger towns), London boroughs (LBs), urban areas (metropolitan boroughs and urban districts), and rural areas within counties. Eighty-three towns were recognised as CBs before the 1974 reorganisation. Three of these became CBs after 1960 and in the analysis are classed as metropolitan boroughs. The London Government Act of 1963 defined thirty-three LBs: fifteen were aggregates of thirty-two former LBs; eighteen were previously urban areas of four counties adjacent to London and are classed as such in our analysis. There are fifty-eight counties but we included an additional county, Middlesex (metropolitan boroughs and urban districts only), which had been absorbed into London after the 1963 Act. In this paper England and Wales is therefore divided into two hundred and twelve local authority areas comprising eighty CBs, fifteen LBs, fifty-nine urban areas and fifty-eight rural areas.

We have divided the causes of infant deaths into five groups according to Woolf's[8] classification: congenital causes (Registrar General, 1921, short list nos 27, 28); bronchitis and pneumonia (18–19); infectious diseases (2–9, 13); diarrhoea (1, 22); and other. Because specific causes of infant death are recorded only from 1921, our analysis is based on the five years from 1921 to 1925. We have examined the relation between different causes of adult and infant death by age, sex, and geographical area using correlation coefficients and scatter plots. The coefficients are influenced by the numbers of deaths as well as by the strength of the relation. During 1921–25 there were 291 082 infant deaths, 127 796 in the first month of life (neonatal) and 163 286 thereafter (postneonatal). Death was attributed to congenital causes in 118 514, bronchitis and pneumonia in 61 770, infectious diseases in 20 668, diarrhoea in 31 147, and other reasons in 58 983. Calculations of rates for ischaemic heart disease during 1968–78 for ages thirty-five to seventy-four years, are based on 649 817 deaths in men and 273 017 in women: the average annual rates were 5722 deaths per million men and 2184 per million women. Deaths from other causes ranged from 48 636 for rheumatic heart disease up to 279 343 for lung cancer.

### RESULTS

The infant mortality rate during 1921–25 was 76 per 1000 births. It ranged from 44 per 1000 births in rural West Sussex to 114 in Burnley CB. The overall rates were 88 for the CBs, 70 for the LBs, 73 for the urban areas, and 65 for the rural areas. SMRs for ischaemic heart disease ranged from 70 to 140 in men and from 46 to 148 in women. In men they were 107 for the CBs, 90 for the LBs, 101 for the urban areas, and 91 for the rural areas. The corresponding figures for women were 109, 83, 99, and 92.

The correlations between infant mortality and the SMRs from the leading causes of death during 1968–78 are shown in table I. There was a high correlation for ischaemic heart disease (0·73); and, in descending order, chronic bronchitis and emphysema, cancer of the stomach, and chronic rheumatic heart disease, were similarly highly correlated. Below these were cervical cancer (0·60), stroke (0·54, defined as cerebrovascular disease other than subarachnoid haemorrhage), cancer of the rectum (0·51), accidental falls (0·49), and lung cancer (0·46). Stroke is included in subsequent analyses because of its association with

TABLE I—CORRELATION OF CAUSE OF DEATH (SMRS*) AT AGES 35–74 YEARS IN BOTH SEXES AND INFANT MORTALITY RATES

| Cause of death | ICD no, 8th revision | Correlation coefficient |
|---|---|---|
| Ischaemic heart disease | 410–414 | 0·73 |
| Bronchitis | 490–492 | 0·82 |
| Stomach cancer | 151 | 0·79 |
| Rheumatic heart disease | 393–398 | 0·72 |
| Stroke | 431–438 | 0·54 |
| Lung cancer | 162 | 0·46 |

*Standardised mortality ratios.

hypertension, a risk factor for ischaemic heart disease; and lung cancer is included because of its association with cigarette smoking. We also calculated correlations with infant mortality in each successive five-year period from 1911 to 1960. For the diseases in table I the coefficients for 1911–15 were close to those for 1921–25. After this the coefficients became lower: for ischaemic heart disease they had fallen to 0·56 by 1956–60.

Table II shows the correlations with infant mortality during 1921–25 by sex and age-group. For ischaemic heart disease, bronchitis, stomach cancer, and rheumatic heart disease the coefficients were similar in the two sexes, but those for stroke and lung cancer differed, being higher in men than in women. In each age group, death from ischaemic heart disease was highly correlated with infant mortality.

Table III shows the correlations according to the geographical groups—ie, CBs, LBs, urban areas and rural areas. The coefficients for ischaemic heart disease, stomach cancer, and rheumatic heart disease, varied little between the groups. In women from rural areas there was a lower correlation for bronchitis. The highest correlations for stroke were in the rural areas. Correlations for lung cancer were negative in men from rural areas and in women from each group.

The association between death from ischaemic heart disease in men and women and infant mortality is shown in figs 1 and 2. The statistical dependence is such that an increase in 10 infant deaths per 1000 births corresponds with increases in SMRs of 6·0 in men and 9·0 in women. SMRs for ischaemic heart disease were correlated with those for the other causes of death. The rank order of the coefficients, in both sexes combined, is stroke (0·70), stomach cancer (0·65), bronchitis (0·63), rheumatic heart disease (0·58), and lung cancer (0·26). These values may be compared with 0·73 for infant mortality (table I). Table IV shows the coefficients according to sex and geographical area. Among men the values for stroke were similar to those for infant mortality, whereas among women the overall coefficient was less because of a lower value in urban areas. Correlations with other causes of death were generally lower than those with infant mortality.

TABLE II—CORRELATION OF CAUSES OF DEATH (SMRS) AND INFANT MORTALITY RATES BY SEX AND AGE

| Cause of death | Age group (years) | | | | |
|---|---|---|---|---|---|
| | 35–44 | 45–54 | 55–64 | 65–74 | 35–74 |
| *Men* | | | | | |
| Ischaemic heart disease | 0·57 | 0·68 | 0·69 | 0·57 | 0·69 |
| Bronchitis | 0·42 | 0·78 | 0·82 | 0·76 | 0·81 |
| Stomach cancer | 0·30 | 0·47 | 0·59 | 0·69 | 0·74 |
| Rheumatic heart disease | 0·44 | 0·51 | 0·50 | 0·25 | 0·60 |
| Stroke | 0·33 | 0·55 | 0·64 | 0·49 | 0·60 |
| Lung cancer | 0·47 | 0·64 | 0·55 | 0·37 | 0·52 |
| *Women* | | | | | |
| Ischaemic heart disease | 0·48 | 0·69 | 0·73 | 0·67 | 0·73 |
| Bronchitis | 0·42 | 0·68 | 0·72 | 0·72 | 0·77 |
| Stomach cancer | 0·14 | 0·39 | 0·53 | 0·70 | 0·73 |
| Rheumatic heart disease | 0·63 | 0·71 | 0·58 | 0·43 | 0·70 |
| Stroke | 0·26 | 0·37 | 0·41 | 0·34 | 0·40 |
| Lung cancer | 0·44 | 0·45 | 0·09 | −0·20 | 0·09 |

TABLE III—CORRELATION OF CAUSES OF DEATH (SMRS) AND INFANT MORTALITY RATES IN THREE GEOGRAPHICAL GROUPS IN MEN AND WOMEN

| Cause of death | Geographical group | | | |
|---|---|---|---|---|
| | CBs+LBs | Urban areas | Rural areas | All areas |
| *Men* | | | | |
| Ischaemic heart disease | 0·65 | 0·70 | 0·75 | 0·69 |
| Bronchitis | 0·75 | 0·74 | 0·66 | 0·81 |
| Stomach cancer | 0·73 | 0·63 | 0·73 | 0·74 |
| Rheumatic heart disease | 0·51 | 0·51 | 0·56 | 0·60 |
| Stroke | 0·68 | 0·56 | 0·75 | 0·60 |
| Lung cancer | 0·41 | 0·20 | −0·13 | 0·52 |
| *Women* | | | | |
| Ischaemic heart disease | 0·73 | 0·68 | 0·72 | 0·73 |
| Bronchitis | 0·73 | 0·68 | 0·53 | 0·77 |
| Stomach cancer | 0·68 | 0·66 | 0·78 | 0·73 |
| Rheumatic heart disease | 0·64 | 0·60 | 0·49 | 0·70 |
| Stroke | 0·51 | 0·49 | 0·72 | 0·40 |
| Lung cancer | −0·06 | −0·32 | −0·56 | 0·09 |

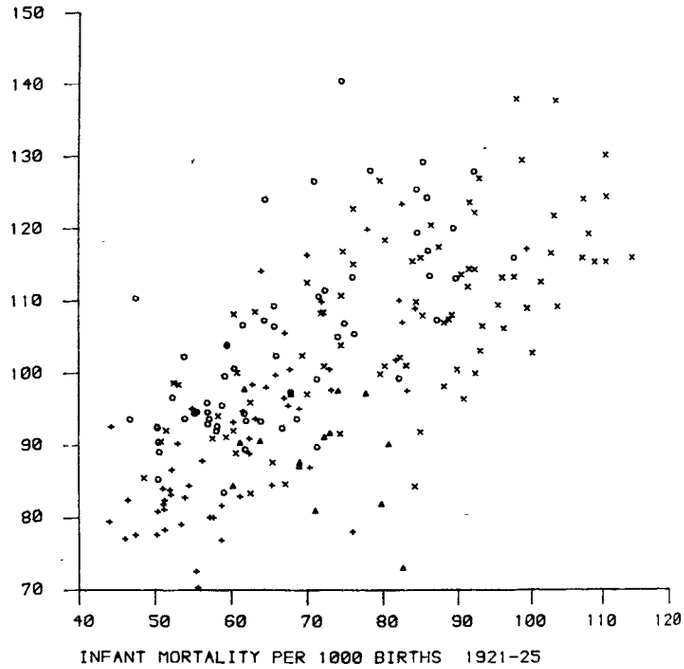


**Fig 1—SMRs for ischaemic heart disease in 1968–78 at ages 35–74, men and infant mortality per 1000 births in 1921–25 in the 212 areas of England and Wales.**

(X = CBs, Δ = LBs, ○ = urban areas, + = rural areas).

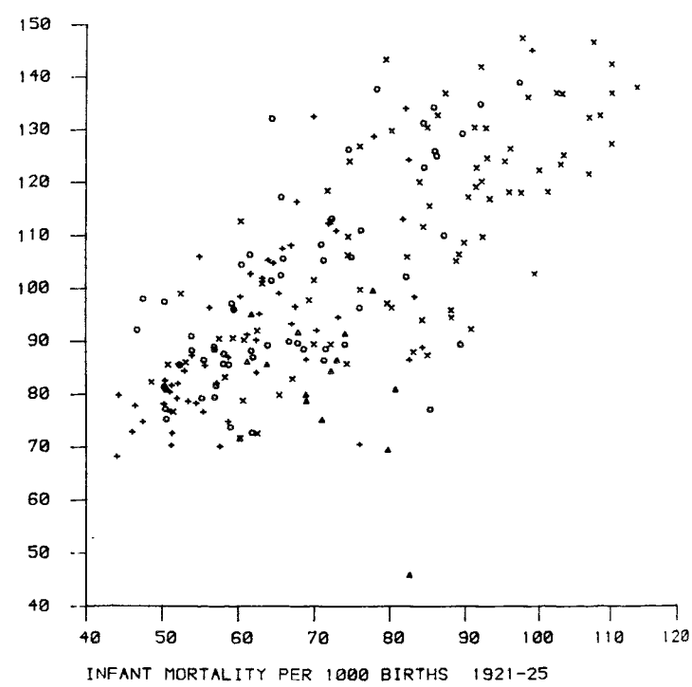


**Fig 2—SMRs for ischaemic heart disease in women and infant mortality.**

TABLE IV—CORRELATION OF DEATH FROM ISCHAEMIC HEART DISEASE AND FROM OTHER CAUSES OF DEATH (SMRS) IN THREE GEOGRAPHICAL GROUPS IN MEN AND WOMEN

| Cause of death | Geographical group | | | |
|---|---|---|---|---|
| | CBs+LBs | Urban areas | Rural areas | All areas |
| *Men* | | | | |
| Bronchitis | 0·49 | 0·49 | 0·67 | 0·58 |
| Stomach cancer | 0·48 | 0·72 | 0·53 | 0·62 |
| Rheumatic heart disease | 0·27 | 0·48 | 0·58 | 0·45 |
| Stroke | 0·73 | 0·68 | 0·78 | 0·72 |
| Lung cancer | 0·18 | −0·09 | −0·03 | 0·30 |
| Infant mortality 1921–25 | 0·65 | 0·70 | 0·75 | 0·69 |
| *Women* | | | | |
| Bronchitis | 0·59 | 0·64 | 0·50 | 0·60 |
| Stomach cancer | 0·64 | 0·36 | 0·43 | 0·57 |
| Rheumatic heart disease | 0·50 | 0·46 | 0·52 | 0·55 |
| Stroke | 0·73 | 0·44 | 0·70 | 0·59 |
| Lung cancer | −0·16 | −0·09 | −0·40 | −0·03 |
| Infant mortality 1921–25 | 0·73 | 0·68 | 0·72 | 0·73 |

Table V shows the correlations between causes of death, neonatal and postneonatal mortality, and causes of infant mortality. There were similar correlations between ischaemic heart disease and neonatal and postneonatal mortality, 0·69 and 0·68, respectively (figs 3 and 4). By contrast bronchitis was more highly correlated with postneonatal mortality (figs 5 and 6) as were stomach cancer and rheumatic heart disease; whereas stroke correlated more closely with neonatal mortality.

In his detailed analysis of infant mortality in the CBs during 1928–38 Woolf[8] found that more than 80% of neonatal deaths were certified as congenital whereas bronchitis and pneumonia was the most common cause of postneonatal death: in keeping with this, the highest correlations with congenital death were for ischaemic heart disease and stroke (table V). Correlations with infant death due to bronchitis and pneumonia were highest for bronchitis. In the LBs neonatal death rates were low while postneonatal rates were high (figs 3 to 6). Correspondingly, SMRs for ischaemic heart disease were low while those for bronchitis were high.

## DISCUSSION

We have shown a close geographical relation between current mortality rates for ischaemic heart disease and past infant mortality rates. Our study was based on the whole of England and Wales, whereas previous reports on the distribution of ischaemic heart disease have been based on selected areas such as towns,[9] or on large geographical areas such as counties and regions.[10,11]

The positive correlations we found between ischaemic heart disease mortality and infant mortality rates are remarkably consistent in both sexes, in all age-groups, and in the different geographical areas. Among the other twenty-four common causes of death only bronchitis, stomach cancer and chronic rheumatic heart disease have a similarly close geographical relation to infant mortality: this is to be

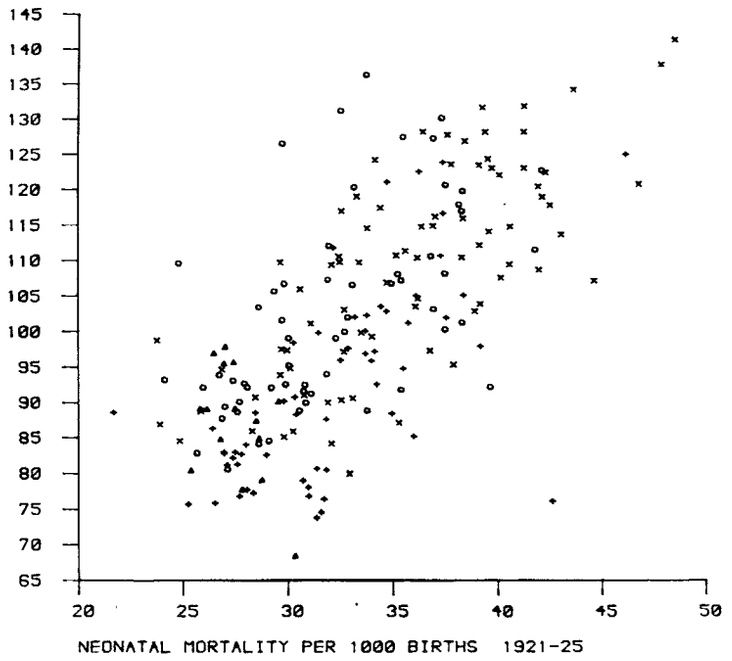


**Fig 3—SMRs for ischaemic heart disease in both sexes and neonatal mortality.**

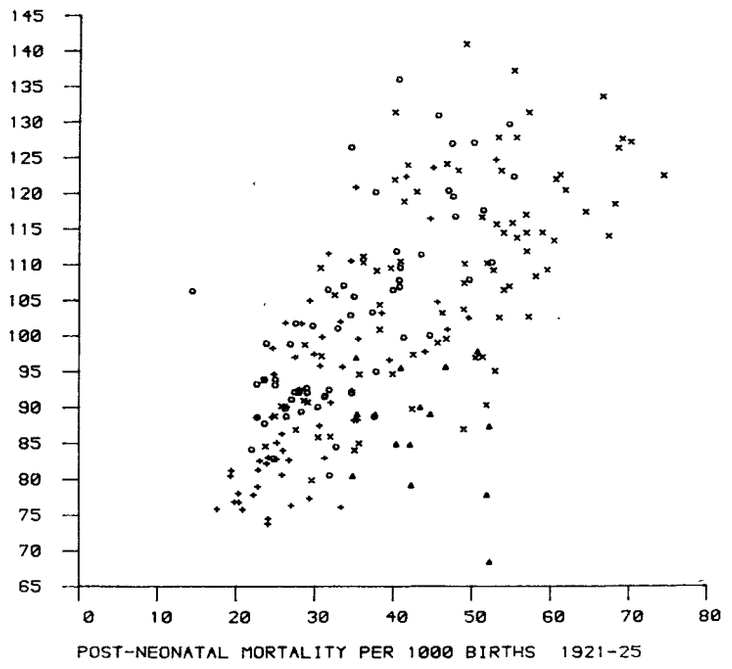


**Fig 4—SMRs for ischaemic heart disease in both sexes and postneonatal mortality.**

TABLE V—CORRELATION OF CAUSES OF DEATH (SMRS) IN BOTH SEXES, AND SPECIFIC INFANT MORTALITY RATES

| Cause of death | Period of infant death | | Cause of infant death | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Neonatal | Post-neonatal | Congenital | Bronchitis & pneumonia | Infectious diseases | Diarrhoea | Other | All |
| Ischaemic heart disease | 0·69 | 0·68 | 0·61 | 0·68 | 0·48 | 0·48 | 0·62 | 0·73 |
| Bronchitis | 0·58 | 0·83 | 0·53 | 0·85 | 0·61 | 0·74 | 0·55 | 0·82 |
| Stomach cancer | 0·61 | 0·78 | 0·52 | 0·71 | 0·66 | 0·63 | 0·69 | 0·79 |
| Rheumatic heart disease | 0·55 | 0·72 | 0·45 | 0·73 | 0·52 | 0·65 | 0·54 | 0·72 |
| Stroke | 0·66 | 0·44 | 0·60 | 0·40 | 0·34 | 0·24 | 0·52 | 0·54 |
| Lung cancer | 0·13 | 0·55 | 0·16 | 0·56 | 0·50 | 0·62 | 0·14 | 0·46 |

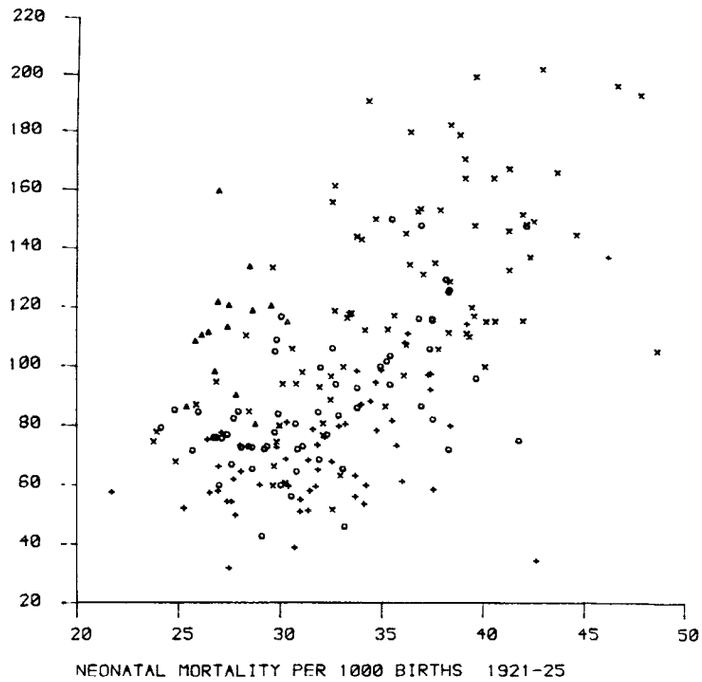


**Fig 5—SMRs for bronchitis in both sexes and neonatal mortality.**

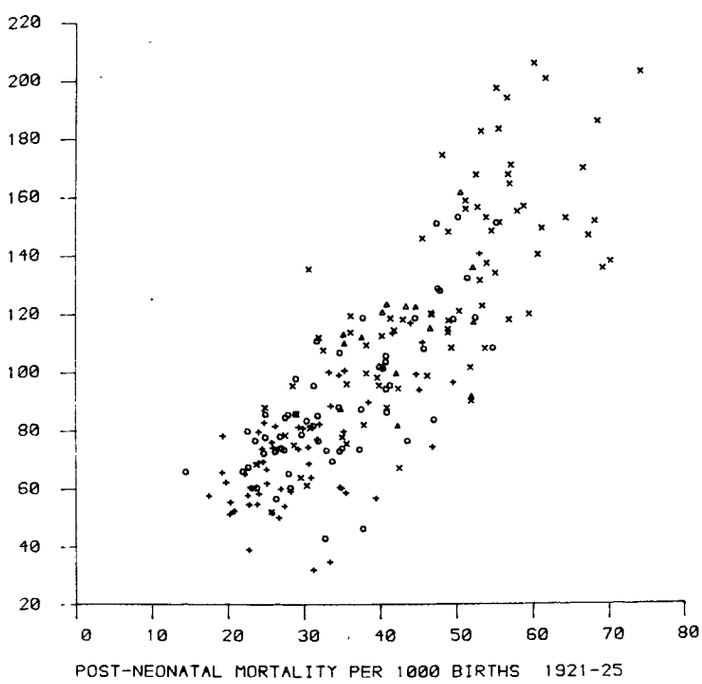


**Fig 6—SMRs for bronchitis in both sexes and postneonatal mortality.**

expected since the three diseases are associated with low socioeconomic groups and their rates, like those for infant mortality, are declining. In 1921 infant mortality rates increased from 38 per 1000 births in socioeconomic group I to 97 per 1000 in group V.[12] In 1971 SMRs for bronchitis and emphysema among men aged 15 to 64 years rose from 36 in group I to 188 in group V. There were similar rises in SMRs for stomach cancer (50 to 147) and chronic rheumatic heart disease (77 to 124).[5] Infant mortality rates began to decline at the turn of the century and fell almost without interruption from 154 per 1000 births in 1900 to 22 per 1000 live births in 1960. Mortality rates for bronchitis, stomach cancer, and rheumatic fever have all declined this century, particularly since 1930.

The geographical relation between past infant mortality and current mortality from three diseases associated with poor living conditions emphasises the paradox of its close relation with ischaemic heart disease, whose rates have increased with greater prosperity. Analysis of the geographical correlations between death from ischaemic heart disease and from other diseases (table IV) gives no additional insight: there are consistent positive correlations with all three diseases and with stroke, as is to be expected from the similar distributions of cerebrovascular and cardiovascular disease in British towns.[13] Apart from stroke no common cause of adult death in 1968–78 correlates as consistently and highly with ischaemic heart disease as does infant mortality during 1921–25.

It is possible that this correlation depends on a factor that is independently related to ischaemic heart disease and infant mortality, although the nature of such an influence is not apparent. The findings for lung cancer show that the social conditions that give rise to infant death do not regularly lead to higher cigarette smoking and hence to raised heart disease rates. In the large CBs the hardness of drinking water is negatively correlated with both ischaemic heart disease and infant mortality.[13] However, if there is a causal relation between water hardness and cardiovascular mortality it seems to be weak.[14] Other environmental influences suspected as causes of ischaemic diseases—for example, dietary fat intake or psychosocial stress—are not known to have the same geographical variations as past infant mortality.

The close geographical similarity between previous infant mortality and current ischaemic heart disease mortality is most readily reconciled with their opposing time trends by the hypothesis that adverse influences in childhood, associated with poor living standards, increase susceptibility to other influences, associated with affluence, encountered in later life.

Findings from other studies support the hypothesis that childhood influences increase the risk of adult heart disease. Rose[15] reported that siblings of ischaemic heart disease patients had stillbirth and infant mortality rates twice those of controls. The inverse relation, among London Civil Servants, between mortality rate and height suggests that factors operating in early life could influence adult death rates from ischaemic heart disease and other diseases, and hence contribute to mortality rate differences between socioeconomic groups.[16] Forsdahl[17] reported a positive correlation between arteriosclerotic heart disease and past infant mortality rates in the 20 counties of Norway and suggested that a poor standard of living in childhood and adolescence was a risk factor in heart disease. Among long-term employees of the Bell System company in the USA, men whose parents had been in "white-collar" occupations had a lower incidence of ischaemic heart disease than those from "blue-collar" families: this was consistent in all job categories and areas of the country.[18]

Examination of the causes of infant death elucidates possible childhood influences on heart disease. Woolf[8] reported that much of the variation in stillbirth and neonatal mortality rates depended on variations in poverty (measured by the percentages of unemployed and employed men in groups IV and V). He attributed this to the adverse effects of poverty on maternal nutrition and lactation. By contrast, postneonatal mortality was influenced by overcrowding (persons per room, population density, and family size), the effect of which was attributed to greater exposure to

respiratory infection. In our study adult mortality rates for bronchitis and chronic rheumatic heart disease are more closely correlated with the geographical variations in postneonatal than neonatal mortality and with infant deaths from bronchitis and pneumonia. Mortality rates for ischaemic heart disease and stroke, however, have a strong correlation with neonatal death, and hence deaths attributed to congenital causes. The low cardiovascular disease rates in the London boroughs emphasise the geographical correlation with neonatal death rates, which are low in London while postneonatal rates are high.

The association of ischaemic heart disease with neonatal mortality suggests that the childhood influences predisposing to it are related to nutrition during prenatal and early postnatal life. The association with postneonatal mortality suggests a continued relation with nutrition throughout infancy. Nutrition in the subsequent years of childhood may also play a role since infant mortality was closely correlated with mortality at ages 1 to 5 years.[19]

Early in this century many infants were poorly nourished. Maternal malnutrition and ill-health and frequent infant intercurrent infection impaired nutrition. Bottle feeding was becoming more frequent although breast feeding remained usual.[20] The composition of artificial infant foods varied and some patent foods were mainly starches.[21] Artificial feeding practices were related to increased infant mortality.[22] The excess deaths were due to a range of illnesses, including both enteric and respiratory infections.[23,24]

The idea that the manner of infant feeding influences metabolism in later life was put forward by Chapin in 1909.[25] Since animal fat is the main source of calories in human milk and is suspected as a cause of ischaemic heart disease, fat metabolism could be one of the links between infant nutrition and the disease. In infants there is evidence of differences in serum cholesterol according to type of feeding.[26,27] In women who were exclusively breast-fed during the first five months of life mean serum cholesterol levels were significantly lower than those who had not been breast-fed; for men the difference was smaller and not significant.[28]

We suggest that the geographical distribution of ischaemic heart disease in England and Wales reflects variations in nutrition in early life, which are expressed pathologically on exposure to later dietary influences. One adult disease whose geographical distribution in England and Wales largely depends on the environment in early life is toxic nodular goitre. Its distribution is determined not by the small variations in the current high levels of dietary iodine intake but by the large variations in earlier low intakes,[29,30] and it is now common only where iodine deficiency was prevalent sixty years ago.

Our hypothesis could account for a number of hitherto unexplained aspects of the epidemiology of ischaemic heart disease. Fifty years ago death from ischaemic heart disease was more common in socioeconomic groups I and II than in IV and V. By 1961 the position was reversed with a larger difference in the younger age-groups.[31] In 1971 SMRs for ischaemic heart disease increased from 88 in group 1 to 111 in group V. Such a change is explicable if historically the higher socioeconomic groups were the first to be exposed to "affluence", and as all groups became more prosperous the difference in ischaemic heart disease mortality rates became dependent on susceptibility. The higher past infant mortality in Scotland than in England and Wales, matches the higher rate of heart disease.[11] The high heart disease rates among immigrants from the Indian subcontinent could also be due to poor childhood nutrition.[32]

We are exploring the cohort time trends of neonatal and postneonatal mortality, ischaemic heart disease and stroke, in small areas within England and Wales. This may give closer insight into whether a fall in mortality from these diseases will follow improvements in nutrition in early childhood.

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