THE INFLUENCE OF EXTERNAL FACTORS ON THE MORTALITY FROM PNEUMONIA IN CHILDHOOD AND LATER ADULT LIFE.

By HILDA M. WOODS.

Pneumonia is well known to be extremely fatal at both extremes of life. In 1923 it was the cause of 3671 deaths per million living at ages under 5 years; between ages 5–24 the death-rate fell to 177 and rose to 376 at ages 25–44. After 45 the increase was rapid and the death-rate reached 2279 per million living for the age group 65–74 and 4100 for all ages over 75 years.

The present investigation is an attempt to compare the influences of the *same* external factors upon the mortality rates in childhood and later adult life. In particular to what degree can the influence of social conditions and environment upon the mortality assigned to pneumonia at these ages be statistically measured?

Data were obtained from the Annual Reports of the Registrar General and also the census reports of England and Wales. The mean mortality rates from pneumonia for the triennium 1921–23 were calculated for the 82 County Boroughs in the age groups under 5 years, 45–64 and 65–74 years.

The statistical indices of social conditions used were: (1) the mean infant mortality rate for 1921–23, (2) overcrowding, measured by the percentage living more than two in a room (census 1921), (3) poverty, indicated by the number of pawnbrokers and moneylenders per 1000 occupied males (census 1921). Nobody doubts that, in a general way, each of these indices is *some* measure of social environment, that in poor quarters of a city infant mortality is higher, there are more persons to a room and more pawnbrokers per head of population than in the quarters inhabited by the well-to-do. But Greenwood and others have shown that the housing conditions of a town are not absolute measures of the economic prosperity of its inhabitants. The height of infant mortality, the prevalence of overcrowding and the proportion of pawnbrokers are clearly influenced by local factors which *may* be independent of and are certainly not highly correlated with social well-being in the ordinary sense of the term, and as these other factors vary from city to city, we must not expect too much from our results. The means and standard deviation are shown in Table I.

The coefficient of correlation between the death-rates from pneumonia at ages 0–5 and 45–64 was $\cdot 617 \pm \cdot 05$, and between ages 0–5 and 65–74 $\cdot 678 \pm \cdot 04$. As would be expected, the relation between the death-rate from pneumonia in young and older people is high and significant. In districts where pneumonia mortality is high in young children it is also high in old people, but there is a fairly large margin between these results and unity.

https://doi.org/10.1017/S0022172400008901 Published online by Cambridge University Press

The same degree of association was found in eighteen large cities of the United States. The correlation between the death-rate from pneumonia at ages 0–5

Table I. 82 *County Boroughs.*

	Means	Stand. dev.
Pneumonia		
Death rate per 10,000		
Ages 0–5	54·52	22·39
45–64	11·02	3·81
65–74	27·93	9·81
Social indices		
Infant mortality per 1000 born	82·56	16·99
Overcrowding percentage living more than two to a room	10·65	8·01
Pawnbrokers per 1000 occupied males	5·68	2·62

and 40–60 was ·752 ± ·07, and between 0–5 and 60–80 ·686 ± ·08. The pneumonia mortality referred to white population only and was based on the years 1919–21.

SOCIAL CONDITIONS.

The next step was to consider the effect of social conditions. The correlation results are given in Table II.

Table II. 82 *County Boroughs. Coefficients of Correlation.*

Pneumonia	
Ages 0–5 and Infant mortality	+·824 ± ·024
45–64 „ „	+·616 ± ·046
65–74 „ „	+·530 ± ·054
Ages 0–5 and Overcrowding	+·548 ± ·052
45–64 „	+·281 ± ·069
65–74 „	+·295 ± ·068
Ages 0–5 and Pawnbrokers	+·423 ± ·061
45–64 „	+·335 ± ·066
64–75 „	+·320 ± ·076

All three correlations of zero order between pneumonia at 0–5 and the social indices are higher than between the latter and the rates of pneumonia in adult age, nor is the explanation that infant mortality includes a sensible number of deaths from pneumonia, because when the correlation between infant mortality and pneumonia mortality for the age group 1–5 was computed, it did not sensibly differ from that above given.

When the first order correlations, eliminating infant mortality or overcrowding were computed, it appeared that the correlation between the pneumonia of 0–5 and that of 45–64 was scarcely sensible when infant mortality was made constant, but in the other cases there was no serious change (see Table II *a*).

Table II *a*. *Partial Correlations.*

Pneumonia	
Ages 0–5 and 45–64 ... ... Infant mortality constant	+·245 ± ·070
Ages 0–5 and 65–74 ... ... Infant mortality constant	+·502 ± ·056
Ages 0–5 and 45–64 ... ... Overcrowding constant	+·576 ± ·050
Ages 0–5 and 65–74 ... ... Overcrowding constant	+·646 ± ·043

https://doi.org/10.1017/S0022172400008901 Published online by Cambridge University Press

Although the actual correlations between the rates of pneumonia at adult ages and the social indices are quite substantial, the variabilities are so great (perhaps too, but this cannot be determined, the regressions are so skew) that the regression equations are but poor means of prediction, and indeed even the inclusion of another variable, *i.e.* overcrowding, does not lead to any sensible improvement (see Table III).

Table III. *Regression Equation. Pneumonia Mortality and Social Indices.*

Pneumonia	Mean error of prediction	% error of prediction
Ages 45–64 $p = \cdot1382\,t \quad -\cdot3882$	2·4	21·7
(where p = measure of pneumonia mortality, and t = measure of infant mortality)		
Ages 65–74 $p = \cdot3061\,t \quad -2\cdot6610$	6·5	23·3
Ages 45–64 $p = 1\cdot9673 + \cdot1116\,t \quad -\cdot0149\,d$	2·3	20·8
(where d = measure of overcrowding)		

These results go no further than to indicate that social conditions, so far as measured by these indices, are substantially correlated with mortality from pneumonia and, on the whole, more highly correlated with mortality from pneumonia in early life.

The next point to be considered is the disturbing influence of pathological type. In England and Wales during 1923, 80 per cent. of the deaths from pneumonia in children under 5 years were certified to be due to broncho-pneumonia and 7 per cent. to be due to lobar-pneumonia; between ages 45–64, 25 per cent. were said to be due to broncho- and 45 per cent. to lobar-pneumonia, and between ages 65–74, 38 per cent. were said to be due to broncho- and 33 per cent. to lobar-pneumonia. Deaths from lobar-pneumonia are extremely rare at ages 0–5; nearly half the deaths from pneumonia at ages 45–64 are ascribed to this form, while at ages 65–74 more deaths are due to broncho-pneumonia. Osler states that broncho-pneumonia prevails more extensively among the poorer classes. The types of pneumonia differ at different periods of life. This may help to explain the reduced correlation between pneumonia at ages 0–5 and 45–64 when Infant Mortality is kept constant and the higher correlation between ages 0–5 and 65–74.

Temperature.

In 1876 Farr remarked that "Pneumonia is not only caused by wounds; it is induced by cold of different degrees of intensity; and the degree in which this cause operates at different ages in the two sexes is only determinable by the analysis of the extensive observations registered in comparison with exact daily and nightly meteorological returns extending over series of years."

In a recent report, Young attempted to measure the influence of weather conditions on the mortality from pneumonia in young children. His results were based on an analysis of the mean monthly temperature for 44 years in London and four Scottish cities, and the monthly deaths from pneumonia in

children under 5 years. He concluded from his investigation that no definite association could be shown by correlating the monthly deaths with the mean monthly temperature. In no instance did the correlation coefficients between pneumonia deaths and temperature in London exceed ·20.

Excess mortality from respiratory diseases is commonly credited to unfavourable weather conditions, but temperature does not appear to have any significant relationship with the number of deaths from pneumonia in young children. Dr Young kindly supplied the figures for the mean monthly temperature in London used in his enquiry, and these were correlated with the monthly deaths from pneumonia at ages 40–60 and 60–80. (The figures were not available for the age groups 45–64 and 65–74). Only the winter months, October to March, were examined and the period taken was from 1855–1904. The mean monthly deaths in each age group were corrected for changes in population during the period investigated.

Table IV shows the results for the age group 40–60.

Table IV. *London* 1855–1904.

	Deaths from pneumonia, ages 40–60		Mean temperature (F.)	
	Means	Stand. dev.	Means	Stand. dev.
January	82·1	44·65	38·4	3·32
February	68·9	27·19	39·9	3·71
March	71·3	27·74	42·4	2·73
October	43·9	15·17	50·1	2·40
November	55·8	16·66	43·4	2·42
December	63·9	28·18	39·5	3·46

Coefficients of Correlation between Pneumonia Deaths and Temperature.

	Adults 40–60	(Young London) 1876–1919 Children 0–5
January	$-\cdot148\pm\cdot093$	$+\cdot156$
February	$-\cdot454\pm\cdot076$	$-\cdot131$
March	$-\cdot311\pm\cdot086$	$-\cdot154$
October	$-\cdot385\pm\cdot081$	$+\cdot052$
November	$+\cdot024\pm\cdot095$	$-\cdot191$
December	$-\cdot393\pm\cdot081$	$-\cdot046$

It will be seen from the table that the mean number of deaths from pneumonia increases as the mean temperature decreases. The correlation coefficients, with one exception, show a consistent inverse relationship between the number of deaths from pneumonia and temperature. The correlation coefficients for February, March, October and December are significant, and for January and November insignificant. It was found that in January there were an excessive number of deaths during the great influenza epidemic years of 1890–93. When these years were omitted the correlation between the number of deaths from pneumonia in January and the mean monthly temperature became $-\cdot335\pm\cdot085$, which is definitely significant, being more than four times its probable error. The correlation results obtained by Young for children under 5 years are given in Table IV for the corresponding months examined for persons aged 40–60. The correlations for young children are very small and in no instance is there a significant association.

There is evidence from this analysis that among persons aged 40–60 the lower the temperature, the greater the fatality from pneumonia, but pneumonia in young children is not apparently influenced by temperature.

The results of the analysis of the effects of temperature on the deaths from pneumonia in the later age group 60–80 are shown in Table V.

Table V. *London* 1855–1901.

	Deaths from pneumonia, ages 60–80		Mean temperature (F.)	
	Means	Stand. dev.	Means	Stand. dev.
January	63·6	38·83	38·3	3·37
February	53·8	20·95	40·0	3·72
March	55·8	24·17	42·3	2·72
October	31·5	12·62	50·5	2·46
November	44·0	14·46	43·3	2·44
December	51·8	19·41	39·5	3·51

Correlation Coefficients between Pneumonia Deaths and Temperature.

January	$-\cdot232\pm\cdot093$	October	$-\cdot358\pm\cdot086$
February	$-\cdot420\pm\cdot081$	November	$-\cdot118\pm\cdot097$
March	$-\cdot315\pm\cdot089$	December	$-\cdot403\pm\cdot082$

These correlations confirm the previous results and give further proof of the association of temperature with deaths from pneumonia in older people. All the correlation coefficients are negative, and, with the exception of January and November, are definitely significant. The explanation shown for the low correlation in January in the previous age groups 40–60 applies equally to the correlation result in this age group 60–80, but it is difficult to explain the persistent low correlation for November.

It was not possible to continue this analysis and examine the effect of temperature on the mortality from pneumonia in early and later life in the County Boroughs of England.

It is interesting to note the results obtained by Russell in his investigation into the influence of fog on the mortality from respiratory diseases. He found that the prevalence of fog associated with a low temperature and frost increased the death-rate in adults but there was no evidence that this climatic condition affected the death-rate in young children.

These results are confirmed by the present investigation. The mortality from pneumonia in young children depends more on social and environmental conditions than upon temperature, while temperature plays a larger part in the mortality in adults.

The whole of the statistical evidence is quite consistent and leads to the inference that temperature variations are more important factors of mortality from pneumonia in the middle-aged and old than in young children. We have already seen, although the evidence is less complete, that social indices are more highly associated with the pneumonia of childhood than with that of later life. But the temperature data relate only to London and our indices of social conditions—for what they are worth—applied to cities all over England. Evidently then it was desirable to repeat the calculations involving

social indices for the subdivisions of the metropolis which, although having the disadvantage of affording fewer varieties, had the advantage of greater statistical homogeneity.

The analysis was similar to that made for the County Boroughs. The coefficients of correlation were calculated between the mean mortality from pneumonia in 1921–23 in the age groups 0–5, 45–64 and 65–74 and measures of social conditions: (1) the mean infant mortality 1921–23, and (2) overcrowding, percentage living more than two in a room (Census 1921). The means and standard deviations with the coefficients of correlation are given in Table VI. It will be seen that pneumonia in young and older ages is highly correlated, and is over ·5 but still far from unity.

Table VI. 28 *Metropolitan Boroughs.*

Pneumonia Death-rate per 10,000.

	Means	Stand. dev.
Ages 0–5	58·0	20·71
45–64	12·8	3·98
65–74	35·3	8·31
Infant mortality	71·8	10·54
Overcrowding	16·5	7·66

Coefficient of Correlation.

Pneumonia ages 0–5 and 45–64	+·597±·082
0–5 and 65–74	+·544±·090
0–5 and infant mortality	+·910±·022
45–64 „ „	+·598±·082
65–74 „ „	+·491±·097
0–5 and overcrowding	+·795±·047
45–64 „	+·697±·066
65–74 „	+·588±·083

Partial Correlations.

Pneumonia ages 0–5 and 45–64 ... ... Infant mortality constant	+·161±·124
Pneumonia ages 0–5 and 65–74 ... ... Infant mortality constant	+·268±·118
Pneumonia ages 0–5 and 45–64 ... ... Overcrowding constant	+·100±·126
Pneumonia ages 0–5 and 65–74 ... ... Overcrowding constant	+·156±·124

The correlation coefficients of social conditions with pneumonia are again highest in young children. When allowance is made for variations in the social factors, the correlation between pneumonia mortality in early and later life becomes small and insignificant. In London there appears to be no significant association between pneumonia in early and later life when social factors are kept constant. This is somewhat different from the County Borough results, when there was still a high correlation between pneumonia in early and later life after the social factors were kept constant. The differences between the London and County Borough results are not significant with regard to their probable errors.

The analysis was now taken a stage further, correlations of the second order

being computed. If we hold constant both the social index and the rate of mortality in one of the three age groups studied, does there remain a significant correlation between the rates of mortality of the remaining two age groups? Table VII provides the means of answering that question. Taking the first half of the table, where infant mortality is the social index, we note that

Table VII. *Metropolitan Boroughs. Coefficients of Correlation.*

Pneumonia ages 0–5 and 45–64	$-\cdot022\pm\cdot127$
Pneumonia ages 65–74 and infant mortality constant	
Pneumonia ages 0–5 and 65–74	$+\cdot219\pm\cdot121$
Pneumonia ages 45–64 and infant mortality constant	
Pneumonia ages 45–64 and 65–74	$+\cdot646\pm\cdot074$
Pneumonia ages 0–5 and infant mortality constant	
Pneumonia ages 0–5 and infant mortality ...	$+\cdot863\pm\cdot033$
Pneumonia ages 45–64 and 65–74 constant	
Pneumonia ages 45–64 and infant mortality ...	$+\cdot219\pm\cdot121$
Pneumonia ages 0–5 and 65–74 constant	
Pneumonia ages 65–74 and infant mortality ...	$-\cdot151\pm\cdot125$
Pneumonia ages 0–5 and 45–64 constant	
Pneumonia ages 0–5 and 45–64	$+\cdot010\pm\cdot127$
Pneumonia ages 65–74 and overcrowding constant	
Pneumonia ages 0–5 and 65–74	$+\cdot121\pm\cdot126$
Pneumonia ages 45–64 and overcrowding constant	
Pneumonia ages 45–64 and 65–74	$+\cdot586\pm\cdot084$
Pneumonia ages 0–5 and overcrowding constant	
Pneumonia ages 0–5 and overcrowding ...	$+\cdot650+\cdot074$
Pneumonia ages 45–64 and 65–74 constant	
Pneumonia ages 45–64 and overcrowding ...	$+\cdot356\pm\cdot111$
Pneumonia ages 0–5 and 65–74 constant	
Pneumonia ages 65–74 and overcrowding ...	$+\cdot023\pm\cdot127$
Pneumonia ages 0–5 and 45–64 constant	

pneumonia mortality at 0–5 remains highly correlated with infant mortality when the remaining variables are held constant, but that neither of the other rates at ages retains any significant correlation. When the percentage overcrowded is substituted for infant mortality as a social index, it is seen again that there is a substantial residual correlation between the index and pneumonia mortality at ages 0–5, while there is also a significant if smaller correlation between overcrowding and pneumonia mortality in middle life. With respect to the association between the rates of mortality, when the index and the third rate of mortality are neutralised, there is a persistent high correlation between the rates of the adjacent age groups, 45–64 and 65–74, none between the widely separated age groups. It is, of course, realised that this analysis rests upon a comparatively slender basis and nobody with much experience of medical statistics supposes that the method of multiple correlation (or any other method) carried so far as the available data permit one to carry it, can succeed in isolating the significant factors and only the significant factors. Yet the inferences suggested by Table VII are fully consistent with those indicated by the study of temperature. They are these. That an environmental factor of the sociological order, more or less imperfectly measured by infant mortality or percentage overcrowding, is of much importance in the determination of pneumonia mortality in early childhood. This same factor

is important but less important as a factor of mortality from pneumonia in middle life and cannot be shown to have any importance in later life. Another environmental factor, not of sociological order nor directly amenable to human control, viz. changes of temperature, in effect falls of temperature, increases mortality in the later years of life, but is not a substantial factor of infant mortality. Leaving out of consideration—not because it is unimportant but because the data afford no means of measuring it—the possibility that both infant mortality and overcrowding are only indirectly environmental indices, are rather measures of fitness in the eugenic sense, and assuming that the "common-sense" view is just, the analysis leads to the conclusion that the pneumonia mortality of young childhood is largely preventable and that there is some, perhaps a large element of preventability in the mortality from pneumonia of adults between 45 and 64, a time of life, when, as is well known, there are gross differences between the rates of mortality in different parts of the country. Thus the analysis supports the opinion expressed by the Registrar-General that pneumonia is to a large extent a preventable disease, while suggesting that in the late ages this element is small.

REFERENCES.

FARR, W. (1876). *Registrar General's Annual Report*, p. 225.

GREENWOOD, M. (6. v. 1922). The influence of Industrial Employment upon General Health. *Brit. Med. Journ.* I. 708.

OSLER, W. and MCCRAE, T. (1920). *The Principles and Practice of Medicine.* New York and London.

RUSSELL, W. T. (16. viii. 1924). The influence of fog on mortality from Respiratory Diseases. *Lancet*, II. 335.

YOUNG, M. (1924). The influence of weather conditions on the Mortality from Bronchitis and Pneumonia in Children. *Journ. of Hyg.* XXIII. 151–75.

(*MS. received for publication* 7. x. 1926.—Ed.)