A PRELIMINARY STUDY OF THE EPIDEMIOLOGY OF RHEUMATIC FEVER.

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There seems to be considerable evidence in favour of the view that the immediate cause of this acute infective fever is an organism in the form of a streptococcus although there does not yet appear to be unanimity as to the specific characteristics of the latter. With regard to the secondary or indirect or predisposing causes of the complaint, the agencies which influence favourably the development and activity of the organism and consequently the prevalence of the disease, there has been a definite tendency in recent years not only to abandon the hitherto prevailing opinion on the influence of certain meteorological factors, namely, that increase in the amount of rainfall and decrease in the temperature are generally associated with increased incidence of the disease but even to assert that the action of these factors is the reverse of this.

Amongst those who have contributed to the study of the influence of meteorological conditions on the prevalence of rheumatic fever is Sir Arthur Newsholme (1895), whose Milroy Lectures were devoted in part to this section of the subject. This author provides evidence which appears to be at variance with the view that excessive prevalence of rheumatic fever is associated with wet weather and dampness of soil and avers that every statistical fact regarding rheumatic fever contradicts this. He concludes that, as a rule, a heavy annual rainfall is associated with a low amount of rheumatic fever and a small rainfall with an excessive amount though there is no exact proportion observable between the two and further that two or three years of excessive or deficient rainfall are more potent than a single year. He expresses the opinion that deficient rainfall exerts its action from its influence on the level of the ground water and that, while the development of the causal saprophytic organism is favoured by a dry subsoil and a low level of ground water it appears to be drowned out in wet years. As regards the relationship of rheumatic fever to air temperature he states that on the whole it would appear that a high temperature is in England favourable to an increase of rheumatic fever though there is no definite proportion between the two; also that great epidemics of rheumatic fever occur only when the mean temperature of the soil is exceptionally high, *i.e.* over 50° F., and that the greatest epidemics occur when the mean temperature has been thus high for two or three years in succession. Dr Gabbett (1883) from a consideration of the statistics of

admissions to the London Hospital for the period 1873–81 concludes that it is difficult to trace any connection between the state of the weather and the prevalence of the disease in individual years, but that cases of the disease are very numerous at that period of the year during which there is usually a co-existence of low temperature and heavy rainfall, viz. the end of autumn. Drs Greenwood and Thompson (1907) have also investigated the relationship of meteorological factors to the statistics of admissions for rheumatic fever to the London Hospital but for a longer period than Gabbett, namely 1873–1903 inclusive. They state that while the results are not conclusive, a circumstance which they attribute to some extent to the selective character of hospital admissions in general, the inference to be drawn from the correlation between the incidence of disease and rainfall for August—the only month for which a significant coefficient value is found by them—is that rheumatism is associated with dry weather. No definitely significant correlation is found to exist for any month between the admissions to the hospital for rheumatic fever and the mean monthly temperature. Dr Longstaff (1904) concludes that the geographical distribution of rheumatic fever gives no support to the old idea that it is mainly caused by cold, wet, or chills, but that rheumatic fever shows a rough inverse relationship to rainfall and that a dry summer appears to favour an epidemic of rheumatic fever though it is not invariably followed by one. Sir William Church (1906) states that the statistics of the British army show that it is impossible to associate the number of attacks of rheumatic fever with any peculiarity of climate, but that chill is probably a most important factor in determining an attack of rheumatic fever is supported to a certain extent by the geographical distribution of the disease. There is, however, he thinks, some evidence that high and dry lands, where the temperature varies between wide limits in the 24 hours, appear to be particularly conducive to rheumatic fever. F. J. Poynton (1908) draws attention to the frequency of association of rheumatism with damp houses in a series of cases investigated by him. He suggests that the hereditary factor is important but expresses some uncertainty as to what circumstances assist the pernicious effect of the microorganism. Whipman (1888) in his analysis of 655 cases of acute rheumatism in the report of the Collective Investigation Committee of the British Medical Association does not find much definite or reliable information regarding the exact meteorological conditions which influence the prevalence of the disease, although most cases appear to begin in damp and wet or cold and cloudy weather.

The present paper is based on the results of an investigation into the geographical distribution and the secondary or predisposing causes of rheumatic fever in Great Britain. The data that have been utilised are the numbers of deaths of persons from rheumatic fever and rheumatism of the heart in the different age-groups in the registration counties of England and Wales for the period 1901–10 as recorded in the decennial supplement to the report of the Registrar-General of England and the figures for the deaths

amongst persons from rheumatism (including rheumatic fever) in certain groups of registration counties in Scotland for the period 1881–1900, which have been extracted and compiled from the supplements (38th and 48th) to the reports of the Registrar-General for Scotland. These data may be considered to be defective inasmuch that the figures used relate to the numbers of deaths from rheumatic fever and not to the actual numbers of cases. Unfortunately the latter figures are not available. Although the mortality from the disease is small it seems not unreasonable to suppose, however, that it is, despite the opinion held by certain authorities, a fair index of the incidence of the disease.

When the incidence of rheumatic fever in different parts of England and Wales is investigated, it is found that the distribution by districts as indicated by the relative size of the death-rate is by no means uniform. The mortality is, as a rule, decidedly greater in the western and northern than in the eastern and midland counties. This is shown well in Table I which gives the standardised death-rates for rheumatic fever and rheumatism of the heart amongst persons 15 years and upwards for the respective counties of England and Wales in the decennium 1901–10. A similar excess of rheumatic fever is found in the western counties of the lowlands of Scotland, the death-rate reaching its maximum in the county of Renfrew as is shown in Table II. This excessive incidence does not obtain to the same degree, however, in the western counties of the Highlands of Scotland and is not a feature of a few of the counties in the west of England and in Wales. To these exceptions reference will be made later.

The meteorological factors of which the influence has been investigated are rainfall and temperature. The average annual rainfall for each several county has been estimated by superimposing the outlines of the areas with different amounts of rainfall as shown on the map of the British Isles prepared by Dr H. R. Mill, Director of the British Rainfall Organisation, on another map of large size showing the boundaries of the counties. From the latter map it has been possible by the aid of the planimeter to obtain the area of each county, the areas therein with different amounts of average annual rainfall and from these to calculate the average annual fall for the county. The figures for mean actual annual temperature for the respective counties have been obtained by a similar method from a map prepared by Prof. A. J. Herbertson and published in Bartholomew's Meteorological Atlas. In this map the actual temperature in different places is shown and not, as is usual, the temperature reduced to sea-level. It will be readily understood that the mean actual temperature calculated for a complete county from these different values can only be accepted as a fair criterion of the climate to which the majority of the people therein are subject if these are more or less evenly distributed throughout the county as is the case in many counties of England and Wales. It may be easily ascertained by reference to a map of Britain depicting the varying density of the population in persons per

Table I.

Registration County	Mean annual rainfall in inches	Mean actual annual temperature (° F.)	Standardised death-rate for rheumatic fever and rheumatism of the heart from age 15 years and upwards, calculated from data for the period 1901—1910
London	27·5	49·8	0·0687
Surrey	27·3	49·5	0·0551
Kent	26·9	49·7	0·0624
Sussex	28·6	50·4	0·0682
Hampshire	33·5	49·5	0·0572
Berkshire	26·0	49·7	0·0618
Middlesex	27·5	49·8	0·0655
Hertfordshire	27·5	49·3	0·0660
Buckinghamshire ...	27·5	49·1	0·0555
Oxfordshire	27·5	48·9	0·0567
Northamptonshire ...	25·1	48·9	0·0698
Huntingdonshire... ...	22·5	48·0	0·0553
Bedfordshire	25·1	48·1	0·0702
Cambridgeshire	22·5	48·9	0·0599
Essex	22·5	48·9	0·0684
Suffolk	24·2	48·9	0·0560
Norfolk	26·2	48·9	0·0513
Wiltshire	32·1	48·7	0·0545
Dorsetshire	35·0	50·6	0·0556
Devonshire	42·1	50·9	0·0606
Cornwall	47·1	50·3	0·0553
Somersetshire	34·2	49·6	0·0545
Gloucestershire	31·8	49·4	0·0625
Herefordshire	35·1	48·5	0·0694
Shropshire	29·9	48·5	0·0538
Staffordshire	30·9	48·1	0·0720
Worcestershire	27·5	48·8	0·0606
Warwickshire	27·5	48·8	0·0634
Leicestershire	27·5	48·8	0·0608
Rutlandshire	27·5	48·8	0·0693
Lincolnshire	24·7	48·6	0·0570
Nottinghamshire... ...	24·4	48·9	0·0582
Derbyshire	36·1	46·1	0·0654
Cheshire	31·9	47·8	0·0778
Lancashire	41·8	47·2	0·1016
Yorkshire, West Riding...	34·3	46·4	0·0862
,, East Riding ...	26·7	48·1	0·0621
,, North Riding	33·7	46·4	0·0853
Durham	32·5	45·7	0·0844
Northumberland... ...	33·9	45·4	0·0778
Cumberland	41·9	46·4	0·0909
Westmorland	62·4	45·2	0·0878
Monmouthshire	35·8	49·3	0·0864
Glamorganshire	51·6	48·7	0·1067
Carmarthenshire ...	52·8	47·8	0·0914
Pembrokeshire	42·6	49·7	0·0752
Cardiganshire	48·2	47·3	0·0768
Brecknockshire	52·6	45·5	0·0996
Radnorshire	45·8	44·8	0·0514
Montgomeryshire ...	52·9	46·4	0·1035
Flintshire	31·6	48·6	0·0958
Denbighshire	46·8	47·2	0·0854
Merionethshire	65·3	46·1	0·1299
Carnarvonshire	47·9	47·2	0·0813
Anglesey	39·1	49·6	0·0495

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Table II.

Counties or county groups in Scotland	Mean annual rainfall in inches	Mean actual annual temperature (° F.)	Standardised death-rate for rheumatism including rheumatic fever from age 0–45 calculated from data for the period 1881–1900	Standardised death-rate for rheumatism including rheumatic fever from age 45 and upwards calculated from data for the period 1881–1900
1. Sutherland	52·2	44·5	0·0656	0·3159
2. Ross	42·8	44·7	0·0619	0·4033
3. Inverness	53·1	44·3	0·0780	0·4157
4. Argyll	60·0	46·0	0·0744	0·2651
5. Perth, Kinross and Clackmannan	51·6	43·5	0·0704	0·2066
6. Nairn, Elgin, Banff and Aberdeen	33·6	44·4	0·0719	0·1890
7. Kincardine, Forfar and Fife ...	34·3	45·4	0·0592	0·2238
8. Dumbarton and Stirling ...	59·9	45·6	0·0612	0·2159
9. Linlithgow, Edinburgh, Haddington and Berwick ...	33·3	45·3	0·0746	0·2579
10. Peebles, Selkirk and Roxburgh	43·6	43·3	0·0487	0·1740
11. Ayr and Wigton	46·0	46·0	0·1281	0·4062
12. Kirkcudbright and Dumfries...	51·4	45·3	0·1261	0·4820
13. Lanark	43·1	44·4	0·1251	0·4721
14. Renfrew	55·6	45·6	0·1691	0·5987

square mile throughout the country that some of the counties of Scotland, especially those in the west Highlands, are to a very large extent uninhabited, the very scanty population being restricted to certain more or less well-defined areas largely coastal in their distribution. For these counties of Scotland, therefore, and to a less extent for others which have also very few inhabitants in considerable areas the mean actual temperature can thus obviously not be to the same degree as in England, a legitimate criterion of unfavourable climatic conditions and in this circumstance may rest in part at least the explanation of the non-observance in the case of the Scottish counties of the indirect relationship between mean actual temperature and rheumatic fever which is well-marked, as will be shown later, in the counties of England and Wales. The concentration of people in large towns will tend in a similar manner to render the mean actual temperature for the counties a less reliable measure of the climatic conditions to which the inhabitants are actually exposed. It is at the best, however, only an approximate measure and is used because, in an inquiry like this, data as far as possible independent of the personal equation of the observer are essential.

Considering in the first place the relationship between rainfall and the amount of rheumatism it is found that the remarks of previous observers are hardly borne out. The coefficient of correlation between the mean annual rainfall in the 55 counties of England and Wales and the standardised death-rate from rheumatic fever amongst persons from 15 years and upwards in the corresponding counties is very considerable, namely, + 0·683. Being positive and of such magnitude in comparison with its probable error it indicates that in the various counties of England and Wales for the decennial period 1901–10, there is a distinct tendency for excess in amount of rainfall to be associated with an increased death-rate from, and presumably an increased prevalence of, rheumatic fever. When the death-rates from rheumatic

fever in the several counties and the corresponding mean annual temperatures are compared in a similar manner the coefficient of correlation is found to be − 0·538, in this case negative in sign and also significant in value. From this the inference is that a reduced mean temperature has a distinct relationship to the incidence of the disease in the several counties and, since the correlation is inverse, the death-rate is higher and presumably the malady is more prevalent with an excess of cold weather throughout the year.

To differentiate the influence of rainfall from that of temperature the partial correlation coefficients between rainfall and temperature respectively and the standardised death-rate from rheumatic fever in the period 1901–10 have been calculated. It is found that when the temperature is considered to remain constant the coefficient between rainfall and rheumatic fever is + 0·579 while when rainfall is considered constant the coefficient between mean temperature and rheumatism is − 0·338. This suggests that while excess in the amount of rainfall and the amount of cold weather have each a decided influence independently of the other, the excess of rainfall is the more potent factor. By means of a regression equation for rheumatic fever death-rate on mean annual rainfall and mean actual temperature theoretical values have been calculated which when compared with the actual death-rates for rheumatic fever in the counties of England and Wales for the period 1901–10 provide, on the whole, a moderately good fit. A few counties, notable amongst which are Cornwall and Anglesey, show actual values appreciably in defect of the theoretical and others, especially Lancashire and Glamorganshire, have death-rates distinctly in excess of what would be expected. An explanation of the former, and of a similar defect in the counties of the west Highlands of Scotland to be referred to later, may be found in their intimate and extensive relation to the western sea with consequent exposure to a relatively warm rainfall, less liable to cause chills which are so frequently the antecedents of acute rheumatism. In the latter counties, on the other hand, the high degree of urbanisation and unfavourable industrial conditions may, in addition to the meteorological, predispose to an excessive incidence of and death-rate from the disease.

In view of the differences above found it was suggested that in place of taking England and Wales as a whole, sub-division might furnish more definite information. The western counties of England, namely Cornwall, Devon, Somerset, Gloucester, Shropshire, Hereford, Cheshire, Lancashire, Westmorland, Cumberland and those of Wales, in all 23 in number, and the twelve counties on the east coast have been investigated separately. With regard to the first group the correlation between the rheumatic fever death-rate and the rainfall is found to be + 0·595 while that between the temperature and the rheumatic fever death-rate is − 0·477. The coefficient between rainfall and temperature is − 0·579 whence it has been calculated that the partial correlation between rainfall and the rheumatic fever death-rate is + 0·455 and that between mean temperature and rheumatic fever − 0·201.

The coefficients for the eastern counties of England, are respectively + 0·821 for rheumatic fever and rainfall, − 0·756 for rheumatic fever and temperature and the partial correlation coefficients + 0·534 between rheumatic fever and rainfall when temperature is constant and − 0·244 between rheumatic fever and temperature when rainfall is considered constant. As all these coefficients except the last are more than three times their probable error the conclusion may be drawn that the relationship that obtains between rainfall and temperature respectively and rheumatic fever death-rate in the eastern and western groups of counties is very similar to that found to hold for the counties of England and Wales as a whole.

Proceeding now to consider the data for Scotland it is found that these are not so satisfactory to work with. In the supplements to the reports of the Registrar-General the returns for all varieties of rheumatic affections are gathered together under the heading, "rheumatism including rheumatic fever." It is found, however, that the deaths in the age period 0–45 years include the great majority of the deaths from rheumatic fever or acute rheumatism and exclude practically the whole of those from the more chronic conditions. This is shown by an analysis of the figures giving the number of deaths from rheumatic fever and closely allied conditions in Scotland in the different age-groups for the five years period 1901–05. In the annual reports for these years, rheumatic fever, rheumatism of the heart, chronic rheumatism, rheumatic arthritis, rheumatic gout and gout are tabulated separately. Of the total number of deaths from the four last-named diseases less than 10 per cent. occur under 45 years of age and these amount to only 4·2 per cent. of the total deaths in the "rheumatism" group. On the other hand, of the total deaths from rheumatic fever and rheumatism of the heart recorded for the same period, only about 28 per cent. occur after the age of 45 years. The standardised death-rate for rheumatism from age 0–45 years can thus be taken as a fairly reliable measure of the prevalence of rheumatic fever.

The counties of Scotland, as has been mentioned, have, for the purpose of the inquiry, been grouped in 14 groups, the small counties being associated with the adjacent larger counties and contiguous counties of relatively small extent or similar latitude taken together to obtain areas, which, while of convenient extent and furnishing a suitable number of cases are subject to more or less similar conditions. The groups are shown in Table II. The mean annual rainfall for the grouped county areas was first correlated with the standardised death-rate for rheumatism from age 0–45 years in the corresponding regions and the coefficient found was + 0·295. This, while positive in sign like that for the counties of England, can scarcely be regarded as significant on account of its large probable error. When, however, the eastern and southern counties are alone considered the value of the coefficient is increased to + 0·480. The correlation found between actual annual temperature and the death-rate for rheumatic fever in the Scottish counties is also insignificant when allowance is made for its probable error. This may,

however, be partly due, as has been explained, to the unsuitability of mean temperature as a criterion of actual exposure to climatic conditions in some of the counties of Scotland. It is of interest to note that the correlation between the rainfall values for the eastern and southern counties of Scotland and the standardised death-rate for rheumatism from age 45 and upwards for the same epoch, 1881–1900, is + 0·469, which is very similar in value to that found for the age period 0–45 years. This suggests on the part of the cases providing the deaths in the two disease groups—the rheumatic fever and the rheumatoid—a very similar reaction to external or prevailing conditions. Support is given to this view by the circumstance that the correlation between the standardised death-rates for rheumatism in the age-groups 0–45 years and 45 years and upwards is + 0·906. In regard to this it may be mentioned, in view of the contrast it presents, that the correlation coefficient between the standardised death-rates for rheumatic fever and rheumatism of the heart alone in the two age-groups 15–45 years and 45 years and upwards in the counties of England and Wales is + 0·319, a value which suggests some lack of homogeneity in the nature of the cases that are recorded as terminating fatally from rheumatic fever at different ages.

The excessive death-rate from rheumatic fever generally found in the western districts as compared with the eastern which has already been alluded to, suggests the existence of conditions in the former specially favourable to the development and activity of the causal organism. The rheumatic fever death-rate has been shown to be highly correlated with the annual rainfall and when the regional distribution of the latter is examined it is found to exhibit a striking similarity to that of the former. There is the same contrast between the values for the western and those for the eastern counties. The excessive rainfall in the west is principally due to what has been termed purely geographical rain caused by a moist wind blowing from the west or south-west—the direction of the prevailing winds in Britain—against elevated land or mountainous ranges, the amount of the rain being largely determined by the contour of the land and its distance from the sea. With few exceptions of which the principal are Somerset, Gloucester, Hereford, Shropshire, Cheshire and Monmouth the counties in the west of England and in Wales have an average annual rainfall of over 40 inches while that in Westmorland, Glamorgan, Carmarthen, Brecknock, Montgomery and Merioneth exceeds 50 inches. The eastern counties, on the other hand, show, in the majority of instances, an average annual rainfall considerably less in amount and as a rule under 30 inches, the only counties which slightly exceed this figure being Northumberland, Durham and the North Riding of Yorkshire. The eastern counties of Scotland are likewise subject to considerably less rainfall during the year than those further west. The closely analogous distribution of excessive rainfall and excessive incidence of rheumatic fever in the counties of England and Wales described above indicates very strongly that of the meteorological factors which have been investigated excessive rainfall exerts

Table III.

Coefficients of correlation.

Variables	
Standardised death-rate for rheumatic fever for persons from age 15 years and upwards and mean annual rainfall. (55 counties of England and Wales 1901–1910)	+0·683 ± 0·049
Standardised death-rate for rheumatic fever for persons from age 15 years and upwards and mean annual rainfall. (23 western counties of England and Wales 1901–1910)	+0·595 ± 0·091
Standardised death-rate for rheumatic fever for persons from age 15 years and upwards and mean annual rainfall. (12 eastern counties of England 1901–1910)	+0·821 ± 0·063
Standardised death-rate for rheumatic fever for persons from age 15 years and upwards and mean actual annual temperature. (55 counties of England and Wales 1901–1910)	−0·538 ± 0·065
Standardised death-rate for rheumatic fever for persons from age 15 years and upwards and mean actual annual temperature. (23 western counties of England and Wales 1901–1910)	−0·477 ± 0·109
Standardised death-rate for rheumatic fever for persons from age 15 years and upwards and mean actual annual temperature. (12 eastern counties of England 1901–1910)	−0·756 ± 0·083

Table IV.

Partial correlation coefficients.

Variables	
Rheumatic fever death-rate and rainfall with temperature constant. (55 counties, England and Wales, 1901–1910)	+0·579 ± 0·060
Rheumatic fever death-rate and rainfall with temperature constant. (23 western counties, England and Wales 1901–1910)	+0·445 ± 0·113
Rheumatic fever death-rate and rainfall with temperature constant. (12 eastern counties, England 1901–1910)	+0·534 ± 0·139
Rheumatic fever death-rate and temperature with rainfall constant. (55 counties, England and Wales 1901–1910)	−0·338 ± 0·081
Rheumatic fever death-rate and temperature with rainfall constant. (23 western counties, England and Wales 1901–1910)	−0·201 ± 0·135
Rheumatic fever death-rate and temperature with rainfall constant. (12 eastern counties, England 1901–1910)	−0·244 ± 0·183

a predominant influence on the prevalence of the disease. While the mean actual temperature may not be in some districts, for the reasons already given, a sufficiently reliable criterion of unfavourable climatic conditions, the relatively high inverse correlation found in the counties of England and Wales between it and the death-rate for rheumatic fever undoubtedly suggests that it also is of considerable importance as a causal factor and that an excessive amount of cold weather is closely associated with an excessive incidence of the disease.

As these conclusions indicate divergence from prevalent views they seem to suggest the need for further investigation into some of what are more or less generally regarded as important amongst the predisposing causes of rheumatic fever, a disease of special interest on account of the frequency and seriousness of the complications liable to follow its onset.

REFERENCES.

CHURCH, Sir W. (1906). "Rheumatic Fever" in Allbutt and Rolleston's *System of Medicine*, II. 594.

GABBETT, H. S. (1883). On the Seasons of the Year and the Prevalence of Acute Rheumatism. *Lancet*, II. 675.

GREENWOOD, M. and THOMPSON, T. (1907). On Meteorological Factors in the Aetiology of Acute Rheumatism. *Journ. of Hyg.* VII. 171.

LONGSTAFF, G. B. (1905). A Contribution to the Aetiology of Rheumatic Fever. *Trans. of Epidem. Soc. of London*, N.S. XXIV. 33.

NEWSHOLME, Sir A. (1895). The Natural History and Affinities of Rheumatic Fever: A Study in Epidemiology. The Milroy Lectures, *Lancet*, I. 657.

—— (1895). The Epidemiology of Rheumatic Fever. *The Practitioner*, LXVI. 11.

POYNTON, F. J. (1904). *Clinical Lectures on Rheumatic Fever*: Endocarditis.

—— (1908). A Contribution to the Study of Rheumatism based upon a Study of 52 cases in Children. *Quart. Journ. of Med.* I. 225.

WHIPMAN, T. (1888). Acute Rheumatism. Reports of Collective Investigation Committee, B.M.A. *British Med. Journal*, I. 387.