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ON METEOROLOGICAL FACTORS IN THE AETIOLOGY OF ACUTE RHEUMATISM.

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(*Four Diagrams.*)

MANY writers having observed that cases of acute rheumatism are not distributed evenly throughout the year, much study has been devoted to the possible relationship between these variations and meteorological conditions.

On this question difference of opinion exists. The problem is a complex one since any complete investigation must include the study of several factors the intensity of which is variable. One of these, humidity, has attracted particular attention, being regarded by many as a causative agent (Garrod[1], Lebert, etc.). On the other hand, some authors consider the relation between rheumatism and humidity to be an inverse one (Longstaff, Newsholme, etc.). Gabbett (1883) could trace no marked coincidence between the curves of rheumatism and rainfall in his series, and Přibram (1899, pp. 355—356) found that "Dagegen war eine auffallende Beziehung zwischen dem Gange der Curve der Niederschläge und der Feuchtigkeitsprocente der Luft und dem Auftreten des acuten Gelenkrheumatismus (im Jahresdurchschnitte) insofern zu erkennen, als im allgemeinen der mehrjährigen Dauer rheumatismusarmer Zeiten, reichlichere Niederschläge und grössere Feuchtigkeit, dagegen den mehrjährigen rheumatismus-reichen Epochen im allgemeinen geringere Niederschlagsmengen und geringere Luftfeuchtigkeit zu entsprechen schienen." In the hope of throwing some light on this question we have recently analysed the statistics of acute

[1] For a full account of the literature see Přibram (1899).

rheumatism admissions to the London Hospital, between the years 1873—1903, and we shall describe in this paper the results obtained.

Before going into the details of this work, it is important to consider certain matters bearing on the general nature of hospital statistics with special reference to the problem under discussion. In a memoir dealing with the statistical results obtainable from the post mortem rooms of a general hospital, one of us (Greenwood, 1904) pointed out that a "General Hospital Population" differs very materially not only from a random sample of the general population, but from one of diseased persons who do not seek hospital treatment. Not only are the majority of hospital inmates drawn from a particular class of the community, but, further, there is a well marked tendency for certain groups of disease to be over-represented.

"Evidently the population of a general hospital will chiefly consist of (1) persons acutely ill, (2) those suffering from surgical injuries or diseases, (3) sufferers from medical affections requiring special treatment. Chronic maladies of old age, such as bronchitis, indeed, any highly chronic disease, will be under-represented in comparison with the general death-rate. Similarly the number of cases of valvular heart disease and rarer disorders, such as diabetes mellitus or insular sclerosis and other nervous lesions, will be above the general average," (Greenwood, 1904, p. 65).

If these considerations be sound, the actual or relative frequency of, for example, acute rheumatism admissions cannot serve as a basis for general reasoning regarding the incidence of this disease among the ordinary population. But a further deduction must be made. Since certain diseases are over-represented in the "General Hospital Population," it must follow that a system of preferential admissions exists, certain types of affection being excluded. If acute rheumatism be among this number, the fact that during certain periods, more cases of acute rheumatism were admitted than usual, would only mean that some other disease was less prevalent, and we could not infer that the causative factors of the former malady were especially active.

We have carefully investigated this point, and our conclusions may be stated as follows. There is no satisfactory evidence that it is the general practice at the London Hospital to exclude cases of acute rheumatism in favour of any other disease. There is, however, some reason to think that in sub-acute cases a certain negative bias exists, and as no hard and fast line can be drawn between acute and sub-acute cases, this lessens to some extent the importance of the material from a

statistical point of view. We shall have occasion to point out later that the existence of such a bias *may*, perhaps, explain a curious discontinuity in our results, at present we merely note its possible existence as a source of error.

The very special character of a "General Hospital Population" cannot be too strongly emphasized. Apparent as is the fact, we find it constantly disregarded. Every year numerous papers are published in which various theories of pathogeny or methods of treatment are supported by appeals to hospital statistics. In general, the statistical methods employed in these writings are so inadequate that just conclusions could hardly be drawn; in the rare instances, in which this is not the case, the fundamental distinctions above drawn have been ignored, a regrettable waste of time and energy resulting.

We have already noted that acute rheumatism exhibits marked seasonal variations in frequency. It might, however, be objected that the discrepancies result from "errors due to random sampling," *i.e.* that if the numbers were larger, the monthly returns would be sensibly equal, on making allowance for the differences in length of the calendar months. That this is not the case seems to be proved by the following considerations.

If there be no bias in favour of any particular season, the number of cases occurring in any thirty-day month will be 30/365 of the total admissions. In other words, the chance in favour of any given case falling in such a month is 30/365, and against the event, 335/365. Consequently, if we know the total admissions for a year, or series of years, we can find the number which should, theoretically, fall in any month. Further, if the actual number admitted exceeds or falls short of this value, we can calculate the chance against such a deviation being merely a result of "random sampling." Thus, in a series of nine years, the number of females with acute rheumatism admitted to the London Hospital in November was 159. The theoretical number on the above hypothesis is 116·71 and the deviation 42·29. Obtaining the value of σ for the normal curve from the expression $\sigma = \sqrt{npq}$, where $n = 1449$, $p = 30/365$ and $q = 335/365$, we find $\sigma = 10{\cdot}93$ (approx.). Hence $\frac{x}{\sigma} = \frac{42{\cdot}29}{10{\cdot}93} = 3{\cdot}87$, and the chance against such a deviation, *or a greater*, occurring is obtained by consulting a table of the probability integral (*see* Sheppard, 1903). This gives 9999456 : 544 or 18,381 to 1 against[1].

[1] This case has merely been given as an example, we attach no importance to the actual figures.

It is therefore clear that some seasonal bias does really exist. These facts are illustrated by the accompanying Diagram 1, which was constructed from fuller *data*. The total number of admissions for acute rheumatism to the London Hospital, from 1873—1903 (inclusive) was reduced to daily averages for each month, so as to render the admissions for different months comparable; a suitable correction was also introduced for Leap Year returns. The figures are as follows:—

January	...	...	·8054
February	...	...	·7460
March	...	...	·6639
April	...	...	·6785
May	...	...	·6347
June	...	...	·7688
July	...	...	·8262
August	...	...	·9095
September	...	...	1·1054
October	...	...	1·1197
November	...	...	1·1591
December	...	...	·9011

These figures are plotted on the diagram. It will be noted that they are in substantial agreement with those of Gabbett, drawn from a shorter series of cases admitted to the same hospital.

We next attempted to refer this discrepancy in monthly returns to meteorological variations, employing the process about to be described.

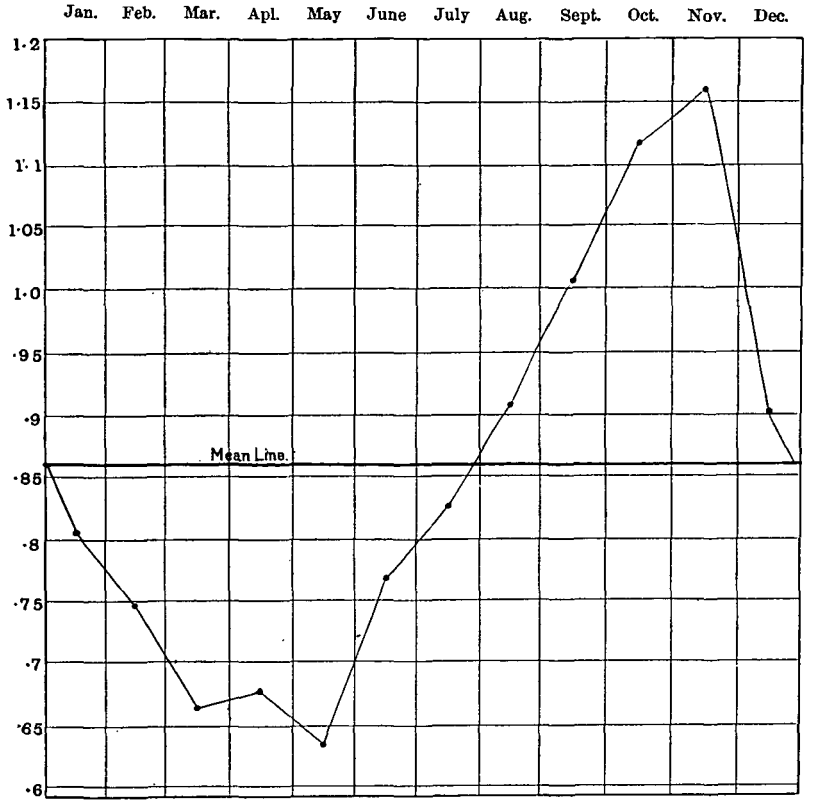
Since the total admissions to the hospital have increased from 1913 (medical admissions) in 1873 to 5196 in 1904, the actual numbers in the different years are not comparable. Hence, we must use as our measure of rheumatism frequency not the absolute numbers, but the ratios of these to the total (medical) admissions for the month, or, if the hospital be usually full, for the year. These ratios were accordingly calculated for the whole series of 372 months from 1873 to 1903.

As criteria of weather conditions we have used:—

(1) The mean monthly rainfall (in inches),
(2) The mean barometric height (in inches),
(3) The mean temperature of the air (Fahrenheit),
(4) Monthly mean degrees of humidity (saturation 100).

(1) was obtained from the paper by Nash (1904). For the *data* under (2), (3), (4) we are indebted to the courtesy of the authorities at the Royal Observatory Greenwich, who most kindly extracted the required information from their Annual Reports.

We had, therefore, two sets of variables, the monthly rheumatism ratios and (1), (2), (3) and (4), so that four series of correlation coefficients could be calculated[1].



Total Monthly Admissions of Acute Rheumatism at the London Hospital from 1873 to 1903 (inclusive). [Reduced to daily averages for each month, so as to render the admissions for different months comparable: a suitable correction also introduced for Leap Years.]

DIAGRAM 1.

[1] It is not possible to discuss here the theory of correlation or methods of calculation; an elementary account will be found in Karl Pearson (1900), *Grammar of Science*, 2nd ed. London, pp. 392 et seq. The coefficient of correlation (r) is a measure of relationship between two variables, it may take any value between 0 and 1. When it is zero the variables are unrelated; when it is unity the relationship is perfect (under "normal" conditions). If the coefficient be positive, the variables increase together; if negative, as one increases, the other decreases.

The "probable error" must always be ascertained. *A coefficient less in magnitude than twice its "probable error" is certainly, and one less than three times its "error" probably, quite without significance.*

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This has been done for the years 1873—1903, with the tabled results. As we had only 31 observations, the moments and products were obtained by referring each individual value to the axes, without forming a correlation table, thus avoiding errors of grouping.

TABLE I.

Rheumatism Ratios and Rainfall.

Month	Rainfall (in inches)		Rheumatism ratios		Correlation r
	Mean	Standard deviation	Mean	Standard deviation	
January	1·66	·96	·00665	·00236	·2447 ± ·1139
February	1·56	·93	·00550	·00171	·1260 ± ·1192
March	1·46	·76	·00533	·00119	− ·1210 ± ·1194
April	1·59	·88	·00535	·00146	·03844 ± ·1210
May	1·75	1·05	·00509	·00139	− ·1385 ± ·1188
June	2·11	1·23	·00605	·00160	·0507 ± ·1208
July	2·45	1·51	·00668	·00192	·1441 ± ·1186
August	2·38	1·30	·00719	·00191	− ·4720 ± ·0942
September	2·03	1·13	·00844	·00225	·2375 ± ·1143
October	2·72	1·56	·00912	·00278	·2595 ± ·1131
November	2·28	·93	·00928	·00244	·01509 ± ·1211
December	1·96	1·06	·00748	·00196	− ·00153 ± ·1211

TABLE II.

Rheumatism Ratios and Mean Barometric Height.

Month	Barometer (in inches)		Correlation with Rheumatism Ratios
	Mean	Standard deviation	
January	29·847	·1914	·0874 ± ·1212
February	29·818	·2131	− ·1113 ± ·1196
March	29·747	·1546	·0816 ± ·1203
April	29·729	·1074	·03282 ± ·1210
May	29·802	·1048	·2614 ± ·1129
June	29·819	·0708	·1827 ± ·1171
July	29·792	·0852	·2807 ± ·1117
August	29·772	·0759	·3576 ± ·1056
September	29·814	1·040	− ·2381 ± ·1143
October	29·734	·1370	− ·1374 ± ·1189
November	29·733	·2709	− ·09413 ± ·1201
December	29·768	·1902	·1446 ± ·1186

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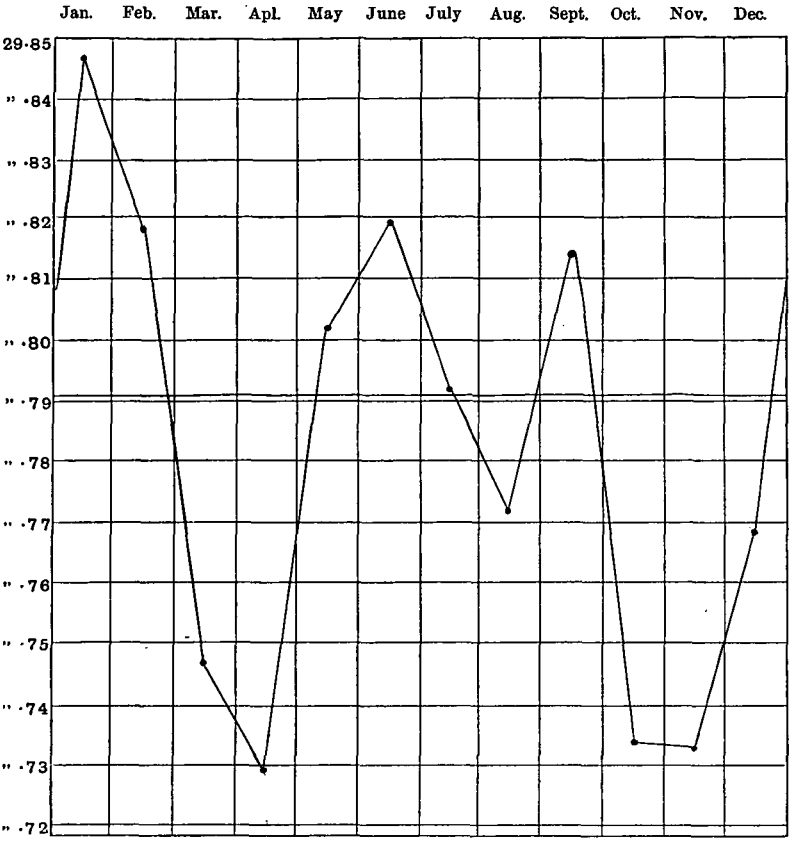

Mean Barometric Height in inches for the years 1873 to 1903 (inclusive).

DIAGRAM 2.

TABLE III.

Rheumatism Ratios and Mean Temperature.

Month	Temperature (in degrees, Fahrenheit) Mean	Standard deviation	Correlation with Rheumatism Ratios
January	38·736	3·64	·2457 ± ·1138
February	39·339	3·55	·1233 ± ·1193
March	41·86	2·73	– ·05092 ± ·1208
April	46·87	1·89	·1375 ± ·1188
May	52·59	2·59	·0527 ± ·1208
June	59·17	1·71	·0789 ± ·1204
July	62·46	2·49	·1757 ± ·1174
August	61·58	2·01	·1378 ± ·1188
September	57·18	2·13	– ·0790 ± ·1204
October	49·47	2·44	– ·1320 ± ·1193
November	44·05	2·44	– ·2324 ± ·1446
December	39·43	3·54	·0821 ± ·1203

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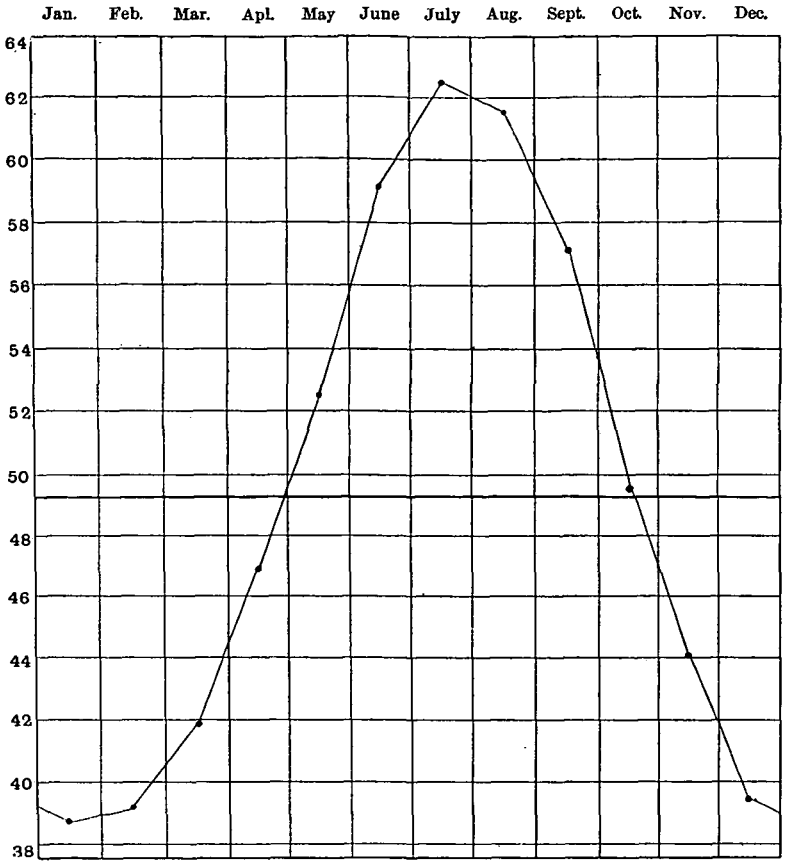

Mean Monthly Temperature in degrees Fahrenheit from 1873 to 1903 (inclusive).

DIAGRAM 3.

TABLE IV.

Rheumatism Ratios and Mean Humidity.

(Only a few of these are given, as the percentage saturation values are of questionable utility from the present standpoint.)

Month	Percentage saturation		Correlation with Rheumatism Ratios
	Mean	Standard deviation	
March	79·85	2·59	−·2636 ± ·1127
May	74·11	3·37	−·1845 ± ·1170
June	73·98	3·90	−·0612 ± ·1207
August	75·93	4·21	−·1935 ± ·1166
September	80·37	3·71	·1701 ± ·1176

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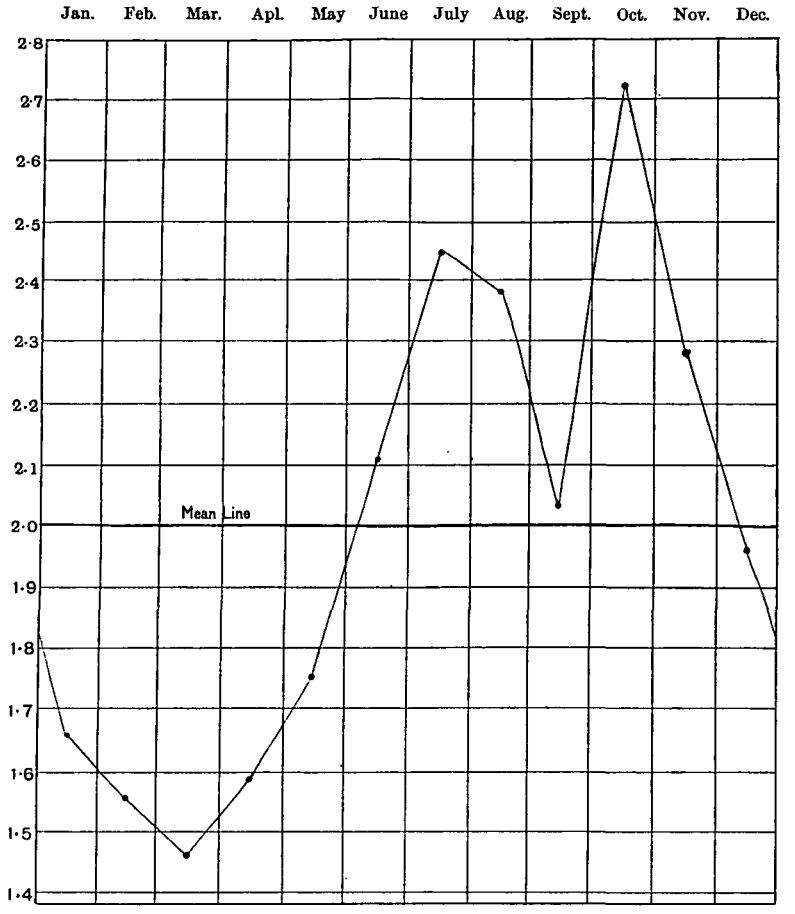

The Mean Monthly Rainfall in inches for the years 1873 to 1903 (inclusive).

DIAGRAM 4.

A comparison of the correlation coefficients with their probable errors shows that, with two exceptions, the results are negligible. Except for the month of August no relation between meteorological conditions and rheumatism can be inferred from our investigation.

It might be suggested that owing to the interval separating the development of the disease and admission to hospital, a relation should rather be sought between the rheumatism returns for one month and the weather variables for the preceding month. We have tested this for the month of August.

The correlation between August rheumatism ratios and July

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rainfall is ·0087 ± ·1211: between the former and July humidity, ·0606 ± ·1207: with July temperature ·0182 ± ·1211. These are all negligible.

As we have said, there is one peculiar exception to the general results, namely the rainfall and barometer correlations for August. In this month alone, we obtain a significant negative correlation between rheumatism ratios and rainfall, a substantial positive correlation between the former and barometric height. The inference being that rheumatism is associated with dry weather as upheld by Newsholme and, to some extent, Přibram.

It is not easy to see why the month of August should occupy a unique position in our return. Meteorologically, this month is not sharply contrasted with its successors or fore-runners in any respect, nor are the rheumatism admissions maximal. It is possible that the explanation is afforded by the selective character of hospital admissions. The factors which have been *asserted* to militate against the admission of rheumatism to a general hospital (necessarily long occupancy of a bed, etc.) would be least operative in a holiday month, when little clinical teaching is given and few "requests" are sent up owing to the usual absence of the senior staff. If this be the case, this month alone yields unbiassed statistics and the positive results obtained are of special interest as probably containing a general truth as to the aetiology of acute rheumatism; but as the explanation depends upon assumptions, the accuracy of which we have not been able to establish, it must be regarded as a pure speculation. To avoid any possible misconception we repeat here that no trustworthy evidence is known to us from which we can infer that a *definite* selection of rheumatism exists at the London Hospital.

Apart from the errors dependent on the peculiar material we have analysed, it may be doubted whether the methods employed are sufficiently delicate. We can only say that, although not ideal, they appear more exact than any other readily available. Thus, a more satisfactory method in theory could be founded on a consideration of the curve of rheumatisms given in the first diagram. This appears to resemble closely a compound harmonic curve. It might therefore be analysed by a mechanical harmonic analyser and its components compared with the periodic rainfall curve. We hoped to be able to make some statement as to this matter, but the necessary instrument and power to use it not being at our disposal, we have employed the method above described. Indeed, we are not satisfied that more definite results would have been obtained.

CONCLUSIONS.

Summing up, our conclusions may be expressed as follows:—

1. Acute rheumatism admissions in a "General Hospital Population" exhibits significant seasonal variations.

2. There is evidence of a connection between rheumatism incidence and dry weather for one series of months.

3. The failure to obtain definite results in a majority of the returns is probably dependent on the special nature of the material and suggests that a satisfactory solution of the problem cannot be obtained from hospital statistics.

4. Statistical results obtained from material of this type cannot be applied without further consideration to a normal population.

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