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NUTRITIONAL IRON-DEFICIENCY ANAEMIA

With Special Reference to Prevalence and Age and Sex Incidence

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During the past four years a large-scale investigation into the aetiology and treatment of iron-deficiency anaemias has been carried out by a team of workers in Aberdeen. A preliminary report was published in the *Journal* in 1933,¹ in which it was shown that anaemia occurred very frequently in adult women belonging to the poorest classes in Aberdeen. Further, it was demonstrated that the anaemia was due to an iron deficiency, in the production of which several factors played a part. Since 1933 our survey has been continued and extended to include a large number of individuals of both sexes and of all ages. In the present communication we propose to confine our attention to the incidence of anaemia in relation to age and sex, and to consider in a subsequent report the aetiological effects of menstruation, pregnancy, lactation, diet, infections, and achlorhydria. The observations to be reported were made on approximately 3,500 individuals, some of whom were examined on several occasions. This number includes the 1,250 men, women, and children who formed the subject of the previous communication.

The individuals concerned represent a cross-section of the poorest classes of the population in Aberdeen and the North-East of Scotland. The subjects had not presented themselves for medical examination because of any symptoms of ill-health, but were volunteers obtained at ante-natal, mother, and child welfare clinics and dispensaries, or at schools and clubs. A large proportion of the individuals were members of families in which the wage-earner was unemployed. Previous investigations² in this class of the community showed that the iron content of the diet was frequently well below the optimal figure of 15 to 20 mg. daily, since it averaged about 10 mg. An iron intake of between 5 and 8 mg. per day was not an uncommon finding. The haemoglobin was estimated by the Haldane haemoglobinometer (where 100 per cent. is the equivalent of 13.8 grams of haemoglobin per 100 c.cm. of blood). The instruments were checked at regular intervals against a tube standardized by Dr. C. Price-Jones.

Standards Adopted

In order to estimate the incidence of anaemia it is necessary to consider the normal standards for the groups under review. From the figures given in the literature it is difficult to arrive at satisfactory conclusions. The

main reasons for this are the diversity of methods used for the estimation of haemoglobin in the blood, and the apparent differences in the haemoglobin levels of normal individuals in various countries. Thus Williamson,³ examining 919 individuals in America by the spectrophotometric method, found an average value of 16.92 grams haemoglobin per 100 c.cm. of blood for normal adult males, and 15.55 grams for adult females. Conversion of these figures to the Haldane scale gives haemoglobin values of 122.6 per cent. for males, and 112.7 per cent. for females. Similar findings have been reported by Wintrobe,⁴ using the Newcomer haemoglobinometer. These figures are much higher than the mean values for adult males and females in this country published by Price-Jones,⁵ though in agreement with the results of Jenkins and Don.⁶ Our own experience is in keeping with the former, and accordingly we prefer to accept the Price-Jones standards of normality. A review of the literature afforded little help in regard to the normal haemoglobin concentration in children and adolescents. Of twenty-five children of the better classes between the ages of 1 and 5 years, observed by Spence,⁸ twenty had haemoglobin concentrations between 75 and 84 per cent. on the Sahli-Leitz scale, or between 85 and 95 per cent. on the Haldane scale.

We have decided to adopt the following normal standards:

1. Infants over 5 months of age, 86 per cent. This was the average figure obtained by Helen Mackay⁷ for breast-fed infants after iron treatment, and may therefore be considered to represent the haemoglobin level in the absence of iron deficiency.

2. Children aged 2 to 5 years, 90 per cent.

3. School children, 95 per cent.; adolescent females, 95 per cent.; and adolescent males, 105 per cent. These standards are based on our observations, which show that about 50 per cent. of individuals belonging to the poorest classes attain these levels.

4. Adult males, 105 per cent.; adult females, 98 per cent., in accordance with the standards established by Price-Jones.⁵

These standards represent, of course, only the average findings in normal individuals; the range of normality extends 10 per cent. above and below. Anaemia cannot be said to be present unless the haemoglobin level is below the lower limit of the normal range.

For convenience the terms "moderate anaemia" and "severe anaemia" are referred to in the text. In infants between 5 and 23 months "moderate anaemia" is taken to represent the haemoglobin range 60 to 74 per cent., and "severe anaemia" all values below 60 per cent. For adults and adolescents of both sexes "moderate anaemia" denotes a haemoglobin level of 70 to 79 per cent., and "severe anaemia" values below 70 per cent.

Results Obtained

The results of the haemoglobin estimations are summarized in Tables I to V, and plotted in the chart. Below the age of 12 years no distinction is made between the sexes. In the tables the number of individuals examined at each age is shown in the column headed "Number." The haemoglobin values in each age group are arranged in decimal divisions. To facilitate comparison the number of individuals falling within each decimal range is expressed as a percentage of the total number in each group, and is shown in the columns under "Haemoglobin Range." In addition to showing the percentage incidence of the haemoglobin levels, the tables give the average haemoglobin concentration for each group. These are presented in the last column of each table, and have been used in the construction of the chart.

INFANTS

TABLE I.—507 Infants: 1 to 23 Months

Age (Months)	Number	Haemoglobin Range								Average Hb
		40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	
1	12	0	0	0	42	8	8	25	17	90.8
2	50	0	4	18	36	28	12	2	0	77.6
3	49	2	2	16	39	27	12	2	0	77.1
4	62	2	0	10	34	34	19	2	0	80.5
5	50	0	0	10	36	48	2	4	0	79.8
6	61	0	3	15	46	31	5	0	0	77.9
7	48	2	2	4	52	35	4	0	0	77.4
8	37	0	0	8	43	43	5	0	0	78.5
9	44	0	9	7	41	36	7	0	0	77.3
10	28	0	7	14	36	33	4	0	0	75.8
11	16	6	25	19	31	19	0	0	0	63.0
12-17	33	6	12	15	42	12	12	0	0	72.3
18-23	17	0	12	35	41	6	6	0	0	71.5

Table I shows the results obtained in 507 infants aged from 1 to 23 months. In addition, haemoglobin estimations were made on sixty-six infants within twenty-four hours of birth, and on fifty-six infants on the eighth day of life. At birth the haemoglobin levels varied from 103 to 189 per cent., the average being 144.9 per cent. Physiological haemolysis produced a rapid fall to an average value of 132.7 per cent. for infants 8 days old, and 90.8 per cent. for infants between 1 and 2 months. A further fall to 77.6 per cent. occurred in the following month. Thereafter no marked change was noted till the eleventh month, when the effect of iron deficiency became evident in a rapid decline to 68 per cent. Despite the commencement of a mixed dietary at the age of about 9 months, no significant alteration in the haemoglobin concentration was found by the end of the second year of life, and the incidence of anaemia was high throughout this period. Eighty-three per cent. of our infants between the ages of 5 and 23 months fell below the average figure for normal infants (Hb 86 per cent.); 41 per cent. were anaemic (Hb less than 76 per cent.); 29 per cent. were moderately anaemic (Hb 60 to 74 per cent.); and 7 per cent. severely anaemic (Hb less than 60 per cent.).

PRE-SCHOOL CHILDREN

TABLE II.—58 Children: 2 to 5 Years

Age (Years)	Number	Haemoglobin Range							Average Hb
		40-49	50-59	60-69	70-79	80-89	90-99	100-109	
2	19	5	11	11	32	42	0	0	73.0
3	16	0	0	12	19	56	12	0	79.4
4	9	0	0	0	33	44	12	12	83.1
5	14	0	0	0	7	64	29	0	86.0

Table II gives haemoglobin estimations on fifty-eight children. Thirty-two per cent. were found to be anaemic (Hb below 80 per cent.). As the child approached the school age the incidence of anaemia became less, and the average haemoglobin rose steadily to reach the level of 86 per cent. at the fifth year. Spence^s reports that of 121 children from labouring and artisan families in Newcastle-upon-Tyne, 19.8 per cent. had satisfactory haemoglobin values, and 23.1 per cent. were definitely anaemic. For comparison we have converted the standards on the Sahli scale utilized in his assessment to the Haldane scale, and find that of the fifty-eight children examined by us approximately 39 per cent. had satisfactory haemoglobin levels (above 85 per cent.), while 17 per cent. were anaemic (below 73 per cent.). We may conclude, therefore, that a state of anaemia occurs in the industrial areas of England like that in Aberdeen.

OLDER CHILDREN

TABLE III.—44 Children: 6 to 11 Years

Age (Years)	Number	Haemoglobin Range				Average Hb
		70-79	80-89	90-99	100-109	
6	8	0	75	25	0	87.4
7	12	0	35	58	17	90.2
8	7	0	71	29	0	88.0
9	8	0	38	50	12	91.4
10	4	0	25	50	25	92.0
11	5	0	20	60	20	93.0

An average haemoglobin content of 90 per cent. was found in the forty-four subjects of this group. No child was observed to have a concentration less than 80 per cent. In addition to the figures presented in Table III, we have data regarding 750 school children who were not included in the chart because their exact ages were not noted. Careful clinical examination on two occasions of 650 children showed that only 1 per cent. were mildly anaemic. The rarity of anaemia in school children was further confirmed by haemoglobin estimations on the remaining 100, only two of whom showed a mild anaemia (Hb 70 to 84 per cent.). While it is probable that children of the upper classes have higher haemoglobin levels, it is obvious that nutritional anaemia is of little importance in this group.

ADOLESCENTS

TABLE IV.—320 Adolescents: 12 to 18 Years

Sex	Number	Haemoglobin Range						Average Hb
		60-69	70-79	80-89	90-99	100-109	110-119	
Male ...	74	0	0	13	41	42	4	98.8
Female ...	246	1	5	33	40	19	2	91.7

Table IV shows the results obtained in 320 adolescents between the ages of 12 and 18 years. The average haemoglobin level of the seventy-four males is 98.8 per cent. The haemoglobin value was below 90 per cent. only in ten individuals, and no figure below 85 per cent. was obtained. Anaemia appears to be rare and slight in degree among adolescent males. For the 246 adolescent girls the average haemoglobin was 91.7 per cent. Sixteen per cent. fell below 85 per cent. haemoglobin, but only 5 per cent. were moderately anaemic (Hb 70 to 79 per cent.) and 1 per cent. severely anaemic (Hb less than 70 per cent.). The importance of this finding is emphasized by the fact that most of these girls belonged to a club used by the poorest classes in this city. If chlorosis exists to any degree at the present day it should be found in this group, and the rarity of anaemia in these 246 adolescent girls proves that chlorosis of the severe type common thirty years ago has practically disappeared. An incidence of anaemia amounting to 16 per cent. among these girls does, however, contrast with the absence of anaemia in males, and suggests that an iron deficiency of mild degree is liable to occur in adolescent girls of the poorest class.

Table V sets forth the results obtained in 1,677 adults.

(a) Males.—Ninety-three males, ranging in age from 19 to 69 years, were examined. The average haemoglobin was

97 per cent. Only four subjects had haemoglobin levels below 80 per cent., and all of these were found to be suffering from severe organic disease. Although this average level is 8 per cent. less than that established by

ADULTS
TABLE V.—1,677 Adults

	Ages	Number	Haemoglobin Range										Aver. Hb
			20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	
(a) Males...	9-69	93	0	0	2	0	1	1	11	33	42	10	97.0
(b) Nulliparae...	18-29	50	0	0	0	4	2	10	20	50	14	0	89.7
(c) Parous women...	15-44	603	1	2	3	4	6	17	31	31	5	0	81.3
(d) Parous women...	45+	112	0	0	3	3	4	9	34	31	15	2	86.7
(e) Pregnant women...	15-44	819	0	0.5	1	4	2	32	3	12	0.5	0	78.1

Price-Jones for normal males of the better class, it is apparent that in the absence of organic disease an iron-deficiency anaemia does not occur in males.

(b) Nulliparae (18 to 29 years).—The fifty women of this group had an average haemoglobin concentration of 89.7 per cent. Twenty-five per cent. were anaemic (Hb less

Chart showing average haemoglobin level among poor persons of all ages and both sexes.

than 85 per cent.) ; 10 per cent. showed a moderate anaemia (Hb 70 to 79 per cent.) ; and 6 per cent. a severe anaemia (Hb below 70 per cent.). Reference to the chart indicates that the curve for nulliparae falls abruptly from a level of 95.4 per cent. haemoglobin at 18 years to 83 per cent. haemoglobin as the average value for the age group 25 to 29 years. These findings suggest that an iron-deficiency anaemia may arise in nulliparous females of this social class with advancing age, but the small figures available in the older age groups do not warrant a definite conclusion.

(c) *Parous Women* (15 to 44 years).—Haemoglobin estimations were made on 603 non-pregnant women who had borne children. At least two months had elapsed between examination and the termination of the last pregnancy. Eighty-eight per cent. of this group fell below the standard (98 per cent.) established by Price-Jones for normal women ; 17 per cent. showed a moderate anaemia, and 16 per cent. a severe anaemia. Taking 85 per cent. haemoglobin as the lower limit of the normal range for women, 48 per cent. of these women were below this level. Thus a high incidence of anaemia is found in this group. Reference to the chart shows that the average haemoglobin level falls steadily as the age increases.

(d) *Parous Women* (45 years and over).—Haemoglobin estimations of 112 non-pregnant women of 45 years of age and over who had borne children yielded an average level of 86.7 per cent. Nine per cent. showed a moderate anaemia, and 10 per cent. a severe anaemia. In all, 36 per cent. fell below 85 per cent. haemoglobin. It is seen that in this older group of women the average haemoglobin level was higher, and the incidence of anaemia less, than in the younger women. These findings are reflected in the rise of the average haemoglobin curve which occurs after the menopause (see chart).

(e) *Pregnant Women* (15 to 44 years).—Eight hundred and nineteen subjects are included in this group. The average haemoglobin percentage, irrespective of the month of gestation, was 78.1 per cent. for the entire group. Seventy per cent. were anaemic (Hb less than 85 per cent.) ; 32 per cent. were moderately anaemic ; and 17.5 per cent. severely anaemic. The average haemoglobin level was therefore lower, and the incidence of anaemia higher, than in non-pregnant women of the same age group. These slight differences can probably be explained by the physiological hydraemia which exists during pregnancy. The parallelism between the curves for pregnant and non-pregnant women is striking (see chart).

Discussion

From the figures given in the tables and from a study of the curve based on the average haemoglobin percentages, it is apparent that anaemia is relatively infrequent and of minor clinical importance except at two age periods—infants between the eleventh and twenty-third months of life, and adult women. The incidence of anaemia is highest in women of the reproductive age who have borne children, and is most marked in the latter part of this period. The same findings are obtained among pregnant women. After the menopause there is a lowering of the prevalence of anaemia.

It is a striking fact that anaemia is of such frequent occurrence in infants born of a group of women showing a high incidence of anaemia. We would suggest that this can be explained only as a result of some aetiological factor common to both groups. The influence of age and sex in the production of the anaemia has been clearly demonstrated. The high incidence of anaemia in women, in contrast with its absence in men of the same social

status, is striking, and justifies the conclusion that the physiological demands for iron conditioned by pregnancy and menstruation are not satisfactorily supplied by the diets of many women of the poorest classes. Hence the term "nutritional anaemia" would appear to be justified. A further two years' study of this problem has supplied no information which would induce us to alter our conclusions published in 1933—namely, that an iron-deficiency nutritional anaemia occurs with great frequency among women of the poorest classes, leading to loss of economic efficiency and ill-health ; and that this anaemia can be adequately and cheaply treated by the administration of iron salts.

Conclusions

1. Observations are reported on the haemoglobin levels of 3,500 individuals of both sexes and at all ages. Anaemia was found to be present in 41 per cent. of infants under 2 years, 32 per cent. of pre-school children, 2 per cent. of school children, 16 per cent. of adolescent women, and 45 per cent. of adult women. It was absent in adolescent and adult males, except in association with organic disease.

2. The influence of age and sex in the production of anaemia is demonstrated.

We wish to express our indebtedness to the directors and staff of the Aberdeen Maternity Hospital, the public health authorities, particularly Dr. J. A. Stephen, the director of education for the City of Aberdeen, and to the organizing secretaries of St. Katherine's Club, without whose co-operation this investigation would have been impossible.

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H. I. Schou (*Hospitalstidende*, May 21st, 1935) has counted the cases of neurasthenia, hysteria, and kindred nervous disorders treated in the Danish public hospitals during the past fifteen years, and finds that in this period there has been a rise of about 255 per cent., which, considering the increase of hospital accommodation and hospital treatment, cannot be accepted unreservedly as indicating that the neuroses are rapidly becoming more common. What the figures for the various hospitals do show is that an enormous number of patients suffering from neuroses require hospital treatment and get it, not in institutions specially organized and staffed for them, but in general surgical and medical hospitals, whose costly equipment and administration do not meet the patients' needs. The author gives an account of how Denmark is struggling to get out of this difficulty, and how, in 1928, the Dianalund Nerve Sanatorium was opened. An analysis of 2,500 patients treated in this institution, which according to its statutes is closed to the insane, showed that 50 per cent. of them were in fact insane. There were 20 per cent. suffering from functional neuroses. The remainder suffered either from organic disease of the nervous system or from medical ailments with a nervous element. Inquiries addressed to 300 patients, and answered by 215 of them three years after discharge, showed that more than half were fit for work. The author sees in his institution, notwithstanding its invasion by the definitely insane, the solution to a problem which in the past has meant that while practically every other well-defined disease has had appropriate institutions for its treatment, the victims of neuroses have had to be distributed indiscriminately in general hospitals.