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NUTRITIONAL IRON DEFICIENCY ANAEMIA IN WARTIME*

PART I

THE HAEMOGLOBIN LEVELS OF 831 INFANTS AND CHILDREN

BY

L. S. P. DAVIDSON, B.A., M.D., F.R.C.P.Ed.&Lond. **G. M. M. DONALDSON, M.B., Ch.B.**

M. J. DYAR, M.B., Ch.B. **S. T. LINDSAY, B.Sc., Ph.D.**

J. G. McSORLEY, M.B., Ch.B.

(From the Department of Medicine, University of Edinburgh)

As we enter the fourth year of the war, with its consequent increased mental and physical strain and inevitable dietary restrictions, the assessment of the health of the nation becomes an urgent necessity. Nutritional deficiencies in a population can be assessed in various ways, the estimation of iron deficiency being one method. The advantage of this method is that iron deficiency can be accurately determined by estimation of haemoglobin concentrations. If such an investigation is made on representative samples of the population in wartime the results can then be compared with similar figures obtained in peacetime, and in this way the effect of war conditions on national health can be demonstrated.

Such an investigation is at present being carried out in Edinburgh on infants, school children, and women of child-bearing age, both pregnant and non-pregnant. The survey covers a representative cross-section of Edinburgh working-class population within these groups. This paper deals only with infants and school children ; a second communication will be devoted to the haemoglobin levels in women.

An unselected series of infants and pre-school children from birth to 4 years of age have been examined at the infant clinic attached to the maternity pavilion of the Edinburgh Royal Infirmary, at district welfare clinics, and at wartime nurseries in Edinburgh. The group of school children comprised all the scholars between the ages of 5 and 12 years attending two primary schools which serve working-class districts of Edinburgh. The Haldane haemoglobinometer (13.8 g./100 c.cm. equalling 100%) was employed throughout the investigation. All apparatus used was checked against a standard set.

Infants and Pre-school Children (Birth to 4 Years)

This group comprised 442 individuals: 318 from birth to 23 months, and 124 from 2 to 4 years. None of them had

TABLE I.—*442 Infants and Pre-school Children (Birth to 4 Years). Average Haemoglobin Levels according to Age*

Age ..	< 1 m.	1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.	10 m.	11 m.	12–17 m.	18–25 m.	2 years	3 years	4 years
No. of cases	18	37	42	28	19	15	14	12	13	8	18	11	48	35	29	43	52
Average Hb %	128·3	99	81	76	83	80	79	80	76	77	68·6	72·4	73·9	73	75·3	76·3	76·8

received any iron therapy. A few children between the ages of 9 months and 4 years had been given 25 mg. of vitamin C daily. The results obtained are set out in Tables I and II, and in the accompanying Graph. Of the total number, 142 were examined at "wartime nurseries" which have been set up by the public health authorities to care for children whose mothers are undertaking whole- or part-time war work. Most of these children were supplied with a midday meal in the "nursery."

TABLE II.—*236 Infants and Pre-school Children (10 Months to 4 Years). Average Haemoglobin Levels according to Age*

Age	Welfare Clinics		Wartime Nurseries		Combined	
	Cases	Av. Hb %	Cases	Av. Hb %	Cases	Av. Hb %
10 m.	14	69·6	4	65·0	18	68·6
11 m.	7	72·2	4	72·7	11	72·4
12–17 m. ..	28	77·4	20	69·0	48	73·9
18–23 m. ..	16	73·0	19	73·3	35	73·1
2 yrs.	11	75·8	18	75·0	29	75·3
3 yrs.	8	76·2	35	76·3	43	76·3
4 yrs.	10	77·5	42	79·5	52	76·8
Totals ..	94		142		236	

The haemoglobin levels in the two groups in Table II are very similar, except in the age period 12 to 17 months, when the average haemoglobin level of infants examined at welfare clinics is notably higher than those seen at the wartime nurseries. The significance of this is referred to later.

School Children (5 to 12 Years)

This series consisted of 389 children attending two primary day schools in Edinburgh. The results are set forth in Table III in the form of haemoglobin levels at successive ages, and in Table IV as the percentage of children falling into successive haemoglobin ranges. It will be noted that the average haemoglobin level for the whole series, irrespective of age, is 80.3% (Table III), and 53% of the children have less than 80% of haemoglobin (Table IV).

TABLE III.—*389 School Children (5 to 12 Years). Average Haemoglobin Levels according to Age*

Age	5 yrs.	6 yrs.	7 yrs.	8 yrs.	9 yrs.	10 yrs.	11 yrs.	12 yrs.	Total
No. of cases	19	39	38	66	75	56	75	21	389
Average Hb % ..	81·3	80 0	80·4	76·9	80·6	82·2	80·6	81·0	80·3

TABLE IV.—*Grades of Anaemia in 389 Edinburgh School Children (5 to 12 Years)*

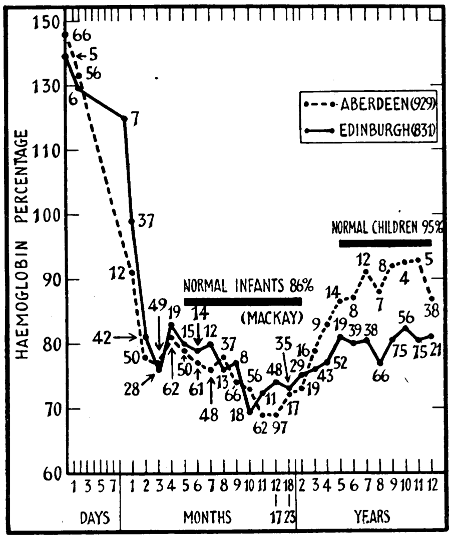
	No. of Cases	Percentage of Children in Different Haemoglobin Ranges			
		Hb 60–70 %	Hb 71–80 %	Hb 81–90 %	Hb > 90 %
School I ..	197	9	46	36	9
School II ..	192	7	44	44	5
Combined ..	389	8	45	40	7

* This subject is still under investigation. Part II, dealing with haemoglobin levels in women, will be published later.

Discussion

Infants (Birth to 23 Months)

A curve has been constructed from the Edinburgh figures in Table I, and is shown in the graph. On the same graph is drawn the curve which was obtained by Davidson *et al.* (1935) in Aberdeen for children of the same age groups.



Graph showing haemoglobin percentages in the present series compared with those of a similar series investigated in Aberdeen in 1935.

The two curves show a close parallelism from birth up to 10 months, with a slightly higher level throughout in the Edinburgh series. From 4 months onwards there is a gradual fall in haemoglobin levels. This fall becomes more acute in both series from the eighth to the eleventh month. There follows a gradual rise until 2 years of age, which is more rapid in the Edinburgh series. The Edinburgh series therefore shows a slight improvement over the Aberdeen series which may or may not be significant. In addition, after the maximum fall in haemoglobin which occurs between the tenth and eleventh months, an earlier and more marked rise takes place in the Edinburgh group. This improvement could be attributed to the better milk supply for infants due to wartime regulations, or to better attendance at infant welfare clinics for expert advice during the critical period of weaning and the inception of a mixed diet. Although it may be some consolation to know that after three years of war no deterioration in haemoglobin levels of infants has been demonstrated, it should not be forgotten that anaemia in infants is still extremely common.

Table V shows the percentage of infants at different haemoglobin levels (2 to 23 months) in the present Edinburgh series, and the comparable figures for Aberdeen and Edinburgh for the age groups 9 to 23 months. This table indicates that

TABLE V.—*Grades of Anaemia in Infants (2 to 23 Months); Edinburgh, 1942, and Aberdeen, 1935*

Place	Age	No. of Cases	Percentage of Children in Different Haemoglobin Ranges			
			Hb < 61%	Hb 61–70%	Hb 71–80%	Hb > 80%
Edinburgh ..	2–23 m.	262	5	23	42	30
Edinburgh ..	2–8 m.	143	4	15	40	41
Edinburgh ..	9–23 m.	119	5	33	45	17
Aberdeen ..	9–23 m.	298	15	23	49	13

the incidence of severe anaemia (less than 61% haemoglobin) in infants of 9 to 23 months in the 1935 Aberdeen series is three times as great as in the 1942 Edinburgh series, but the percentage of moderately anaemic infants (61% to 70% haemoglobin) has risen by 10% in Edinburgh as compared with the Aberdeen figure. It will be noted that 83% of the Edinburgh infants and 87% of the Aberdeen infants between 9 and 23 months have a haemoglobin level of less than 80%.

A haemoglobin level of 86% ± 5 is widely accepted as the ideal for infants from 2 to 23 months. This figure was suggested by Helen Mackay (1933) from her examination of normal infants whose diets had been supplemented by iron. Haemoglobin levels of 80% or less would by this standard be considered subnormal. On this basis only 17% of the infants from 9 to 23 months in Edinburgh and only 13% of the Aberdeen infants had a normal haemoglobin level.

Mackay's figure of 86% seems to us reasonable, since haemoglobin levels of this magnitude and higher were commonly obtained in one of the Edinburgh clinics, where the mothers were particularly keen and intelligent. The higher average haemoglobin level noted in infants of 12 to 17 months examined at welfare clinics as compared with infants of the same age group in the wartime nurseries (Table II) could be explained on the basis of this observation.

The significance of the frequency with which anaemia is still found in infants cannot be overemphasized. The aetiological importance of low birth weight and infections was stressed by Davidson and Fullerton in 1938. The desirability of augmenting the iron intake at the sixth or seventh month in order to counteract the fall in haemoglobin which occurs when the hepatic stores of iron become exhausted needs special emphasis. At first, when mixed feeding has not been fully established, this may best be done by giving small doses of inorganic iron in an easily assimilated form. Later, when the change to mixed feeding has been completed, this may be best accomplished by increasing the intake of foodstuffs rich in available iron. A careful investigation of this problem by paediatricians is obviously required.

Children of Pre-school Age (2 to 5 Years)

A study of the graph shows that any advantage which the Edinburgh series has over the Aberdeen series in infancy is lost during the pre-school period. Thus on entering school at 5 years the Edinburgh children had an average haemoglobin of 81%, compared with an average figure of 87% for the Aberdeen series.

School Children (5 to 12 Years)

As in the case of the infants, a curve has been constructed for the haemoglobin averages of school children in Edinburgh, 1942, and is shown in the graph, together with the curve obtained of school children in Aberdeen, 1935. It will be seen that the number of children in the different age groups is much smaller in the Aberdeen series than in the present Edinburgh series. The Aberdeen figures were obtained from children of the poorest classes, and since the majority of them had haemoglobin levels of 90% or over, it was not considered necessary at the time to carry out further investigation in this age group. In Edinburgh, on the other hand, on completion of the survey of the first group of 197 children, only 9% were found to have haemoglobin levels of over 90% in spite of the fact that these children were in much better social circumstances than those in Aberdeen. Consequently it was deemed advisable to extend the survey to cover a larger group of individuals. A figure of 95% ± 5 selected by us as a standard of normality for healthy school children is based on our own experience, and coincides with the figure given by Whitby and Britton (1939).

The comparison shows that in Edinburgh, 1942, the haemoglobin level throughout this age period is considerably lower than in Aberdeen, 1935, the average difference for all ages being approximately 10%. In spite of this the children did not show obvious signs of malnutrition, and in fact the anaemia would not have been revealed unless haemoglobin estimations had been carried out.

It should be noted that the haemoglobin levels of the children reaching school age were found to be slightly lower in the Edinburgh series than in the pre-war Aberdeen series. Helen Mackay (1942) investigated a series of 364 children comparable in class with our present series. Her average figure for the age group 5 to 13 years was 80%, as compared with the Edinburgh figure of 80.3%. Thus in both these series there is seen to be a fall of approximately 10% from the pre-war Aberdeen figure of 90%.

The analysis of these three series of haemoglobin figures to show the percentage of children in various haemoglobin groups is given in Table VI. This shows that whereas in the Aberdeen series not a single child had a haemoglobin of less than 80%, almost half of the children in Helen Mackay's series and more than half of the children examined by us in Edinburgh had haemoglobin concentrations below that level.

TABLE VI.—*Comparison of Anaemia in 3 Groups of School Children (5 to 12 Years)*

	No. of Cases	Percentage of Children in Different Haemoglobin Ranges			
		Hb < 71%	Hb 71–80%	Hb 81–90%	Hb > 90%
Edinburgh, 1942	389	8	45	40	7
		53		47	
London (Mackay, 1942)	128	42		68	
Aberdeen (Davidson, 1935)	67	0		100	

The children and also the infants in the Aberdeen investigation were drawn from the poorest section of the community at a time when the unemployment rate was extremely high. The weekly income assessed on the basis of "man value"* averaged only about 11s. per head in Aberdeen, in contrast with the present Edinburgh assessment of the family income of 520 women examined at ante-natal clinics, which ranged from 24s. to 39s. per "man value" per week.

It will be appreciated that in peacetime economic status is the chief factor influencing the nutrition of individuals; in wartime, on the contrary, "rationing" and the difficulty in obtaining some unrationed foods constitute the chief limitations, which, broadly speaking, are operative irrespective of income. This is probably the explanation of the higher incidence of anaemia noted by us during the present year in spite of the high figures for "man value" recorded. In support of this conclusion it is significant to note that since obtaining the data already recorded we have examined the haemoglobin concentration of 134 school children aged 5 to 12 years who were pupils in an Edinburgh secondary fee-paying school and who were drawn from a higher social and economic class than the children considered above. The average haemoglobin level for this group was 80.7%, a figure almost identical with that obtained for the 389 working-class children. The percentage of children falling in the different haemoglobin ranges was also similar.

The frequency and degree of anaemia present in school children from working-class families in Edinburgh in 1942 as reported in this paper call for the most careful consideration by both local and national authorities. It is obviously desirable that during the period of active growth and mental development the incidence of anaemia should be reduced to the lowest possible level. This can be achieved by one of two methods or by a combination of both. The first consists in the provision of school meals which are appetizing, well balanced, and rich in foodstuffs with a high iron content. Intensive propaganda must be undertaken to induce a much higher proportion of children to partake of such meals. The need for such propaganda is evident in Edinburgh, where, although the numbers are gradually rising, only some 20% of children are at present taking school meals. The second method is by supplying iron at the schools in the form of a tablet or a mixture, or incorporating it in some article of diet universally eaten, such as bread.

Investigations are at present being undertaken in Edinburgh to discover whether the anaemia can be prevented and corrected by diet alone or whether a supplement of iron is required.

Summary

The haemoglobin levels have been estimated in 831 infants, pre-school children, and school children from working-class families in Edinburgh. The results have been compared with a similar series examined in Aberdeen in 1935.

After three years of war no significant change was found to have occurred in the haemoglobin levels of infants, but a fall has been demonstrated in the case of school children.

* The "man value" figures obtained by us were calculated on the following basis: each member of the family was assessed according to age and sex in terms of one man as one unit, one woman as 0.8 of a man, and a child as 0.5 of a man.

We wish to express our thanks to Prof. Charles McNeil, Dr. G. J. Linklater, school medical officer, and Dr. T. Y. Finlay, medical officer for maternity and child welfare in Edinburgh, for the facilities and help afforded us by them during this investigation.

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PLASMA PROTEIN STORAGE

BY

J. BEATTIE, M.D., D.Sc.

AND

H. B. COLLARD,*, B.A.

Bernhard Baron Research Laboratories, Royal College of Surgeons of England

In a previous paper (Beattie and Collard, 1942) it was stated that after a moderate haemorrhage there was a significant movement of plasma protein into the blood stream. This conclusion was reached by demonstrating that the observed plasma protein concentration of the blood after haemorrhage was greater than a value calculated from the haemoglobin concentration before and after haemorrhage. Dr. Sharpey-Schafer has pointed out to us in a personal communication that the formula used was incorrect and gave expected values which were too high. He suggested the following formula:

$$p1 = p \times \frac{1}{1 + \frac{1}{x}\left(\frac{H}{H1} - 1\right)},$$

where p1 is the plasma protein concentration to be expected at, say, 75 minutes after haemorrhage, p is that observed at, say, 30 minutes after haemorrhage, H and H1 the haemoglobin concentration at 30 and 75 minutes after haemorrhage, and x is the plasma volume % divided by 100 at 30 minutes after haemorrhage. Using this method of calculating the expected value for the plasma protein concentration, we found that we had overestimated the true expected value by varying amounts ranging from about 3 to 15%. Consequently the movement of protein into the blood stream after haemorrhage was, in fact, much greater than we had reported. We are grateful to Dr. Sharpey-Schafer for pointing out our error. This movement of protein observed in anaesthetized cats has been recorded in human subjects bled comparable amounts (Stead, 1940; Wallace and Sharpey-Schafer, 1941). The view was expressed by us that the amount of protein entering the blood was determined probably more by the state of the protein reserves than by any other factor. After plasma transfusions in normal animals there is some evidence of an indirect nature that a movement of plasma protein out of the blood stream may take place (Beattie, 1942). As this outward movement was not constant in all experiments it may well be that it, too, is determined by the state of the protein reserves.

The sites of these reserve stores of protein have not been determined with certainty, but Madden and Whipple (1940), in a review of the evidence, considered that the liver was probably the most important store, although they admitted that direct evidence from hepatectomized animals and perfused liver experiments is at best equivocal. It was decided, therefore, to study the effects of plasma transfusions on hepatectomized animals and of varying protein concentrations in the perfusing fluid in perfused isolated livers. In addition, it was thought that by giving repeated plasma transfusions to normal animals it might be possible to determine whether the plasma protein reserves could be filled up rapidly and so allow the building up of high plasma protein concentrations in the blood within a relatively short time.

* Leverhulme Scholar, Royal College of Surgeons of England.