

DISTRIBUTION OF HAEMOGLOBIN LEVEL IN A GROUP OF SCHOOL CHILDREN AND ITS RELATION TO HEIGHT, WEIGHT, AND OTHER VARIABLES

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It is generally accepted that differences in the mean haemoglobin level in the two sexes become apparent after puberty, and this is thought to be due mainly to a gradual rise in the mean level in boys, which continues until about the age of 16 or 17 years (Sunderman, MacFate, MacFayden, Stevenson, and Copeland, 1953). However, in addition to age and (after puberty) to sex, many other factors are likely to be associated with haemoglobin level. These probably include family size, though this may be merely a reflection of differences in diet. It also seems likely that body mass may be a further associated factor and, if this is true, some, if not all, of the difference in mean haemoglobin between the two sexes may simply reflect differences in body mass. This possibility does not appear to have been examined.

The report which follows presents the results of a survey of haemoglobin levels in school children aged 14 years in eleven Cardiff schools, undertaken to determine the distribution of haemoglobin levels and to examine the associations between those levels and sex, family size, height and weight, and (in girls) menstruation.

METHOD

An attempt was made to see all children, born in 1949, in eleven Cardiff schools. The schools were chosen to give as representative a sample of school

children as possible. Permission to make a haemoglobin estimation at a routine school medical examination was sought from the parents of each child.

A single observer estimated the haemoglobin levels in capillary blood obtained from a finger stab by the alkaline haemalin method, using an EEL photo-electric colorimeter. The levels were estimated as g. haemoglobin per 100 ml. blood and are given here as g.Hb. Height and weight were recorded at the time of examination and each child was asked his or her family size (used here to include only the children at present alive in that child's family), and whether or not menstruation had begun. Different observers (school nurses) measured the heights and weights; these were recorded with the children dressed but without shoes, and are stated in inches and pounds.

In order to examine the association between haemoglobin level and the various factors considered, the children were divided into three main groups: boys; girls who had begun to menstruate; and girls who had not. Each of these groups was further divided by family size into six subgroups. Within each subgroup, the association between haemoglobin level, height, and weight was examined by regression analysis, and differences between subgroups and between main groups were examined by comparisons of the subgroup regressions.

RESULTS

Table I shows the numbers of children involved in the study. Some children were not examined because the parents refused permission, but there was nothing to suggest that refusals were in any way likely to have introduced a bias.

TABLE I
DISTRIBUTION OF SCHOOL CHILDREN BORN IN 1949 IN ELEVEN CARDIFF SCHOOLS, BY SEX, AND WHETHER EXAMINED OR NOT

Sex	Total	Children Examined		Children not examined
		No.	Per cent.	
Male	669	504	75	165
Female	760	620	82	140
Total	1,429	1,124	79	305

Table II shows the distributions of heights, weights, and haemoglobin levels in the three main groups (boys, menstruating girls, and non-menstruating girls). There is evidence of some skewness in the distributions of weight in each, and possibly in the distributions of height in boys and in menstruating girls, but there is no obvious skewness in the distribution of haemoglobin levels within any main group.

Table III (opposite) shows mean heights, weights, and haemoglobin levels with their standard errors in all the subgroups. There is evidence of a fall in each variate with increasing family size, though this trend is not fully consistent; furthermore, the mean haemoglobin level in the boys is significantly higher (at $P < 0.05$, the criterion of significance used throughout this report) than that in the non-menstruating girls, which in turn is significantly higher than that in the menstruating girls. In view of the possible association between the variates, differences between mean haemoglobin levels cannot be readily interpreted, for differences also occur between the main groups in the mean heights (though not all these are significant) and in the mean weights (all of which are significant).

Regression analysis showed that, in the boys, overall regression of haemoglobin level on height and weight is highly significant. There was evidence of differences, which were just significant, in the regressions in the six subgroups defined by family size, but inspection of these regressions showed no evidence of any consistent change in either the sign or the size of the coefficients with increasing family size. It was thought reasonable, therefore, to compare the mean haemoglobin in the six subgroups adjusted to a common height and weight, but this

TABLE II
DISTRIBUTION OF SCHOOL CHILDREN BY HEIGHT, WEIGHT, AND HAEMOGLOBIN LEVEL, SEX, AND (IN GIRLS) BY MENSTRUATION.

in.	Height (in.)			Weight (lb.)				Hb Level (g./100 ml.)			
	Boys	Girls		lb.	Boys	Girls		g.	Boys	Girls	
		Non-Menstruating	Menstruating			Non-Menstruating	Menstruating			Non-Menstruating	Menstruating
<50	—	—	—	50—	—	1	—	10—	—	—	2
51—	—	—	—	—	—	—	—	—	—	—	—
52—	3	1	—	60—	8	2	—	10.5—	1	—	—
53—	4	2	1	—	—	—	—	—	—	—	—
54—	8	3	—	70—	22	17	2	11—	2	—	8
55—	9	1	1	—	—	—	—	—	—	—	—
56—	11	4	5	80—	77	45	24	11.5—	1	—	9
57—	18	15	7	—	—	—	—	—	—	—	—
58—	32	18	24	90—	93	35	79	12—	11	3	25
59—	38	21	33	—	—	—	—	—	—	—	—
60—	45	20	64	100—	93	26	130	12.5—	20	9	44
61—	55	18	78	—	—	—	—	—	—	—	—
62—	53	14	107	110—	86	11	100	13—	34	18	57
63—	57	10	61	—	—	—	—	—	—	—	—
64—	51	10	52	120—	57	3	59	13.5—	107	36	115
65—	47	6	20	—	—	—	—	—	—	—	—
66—	31	—	13	130—	25	2	44	14—	101	33	90
67—	17	—	10	—	—	—	—	—	—	—	—
68—	11	—	—	140—	24	1	15	14.5—	88	29	65
69—	10	1	—	—	—	—	—	—	—	—	—
70+	5	—	—	150—	10	—	10	15—	64	10	31
				160—	4	—	7	15.5—	42	5	22
				170+	6	1	6	16—	23	1	5
								16.5+	11	—	3
Total	505	144	476	Total	505	144	476	Total	505	144	476

TABLE III

DISTRIBUTION OF SCHOOL CHILDREN EXAMINED, BY SEX, FAMILY SIZE, AND (IN FEMALES) MENSTRUATION, SHOWING THE NUMBERS AND MEAN HEIGHT, WEIGHT, AND HAEMOGLOBIN LEVEL (in g.Hb/100 ml. blood) WITHIN EACH GROUP

Sex	Menstruation	Family Size	Number	Mean Height (in.)	Mean Weight (lb.)	Mean Haemoglobin Level (g./100 ml.)
M	—	1	54	63.2 ± 0.43	117.9 ± 2.96	14.65 ± 0.14
M		2	105	62.6 ± 0.36	111.1 ± 2.07	14.35 ± 0.10
M		3	110	62.2 ± 0.30	109.5 ± 2.09	14.50 ± 0.09
M		4	93	61.9 ± 0.39	104.5 ± 2.16	14.50 ± 0.11
M		5	48	61.5 ± 0.52	103.3 ± 2.76	14.12 ± 0.15
M		6+	94	60.3 ± 0.36	99.3 ± 1.89	14.27 ± 0.09
All males			504	61.9 ± 0.16	107.3 ± 0.95	14.40 ± 0.04
F	No	1	9	60.0 ± 1.03	90.0 ± 3.58	14.15 ± 0.30
F		2	37	60.2 ± 0.46	97.7 ± 3.32	14.30 ± 0.12
F		3	30	60.6 ± 0.48	94.2 ± 2.44	13.94 ± 0.13
F		4	25	59.7 ± 0.68	91.4 ± 3.07	13.88 ± 0.17
F		5	16	59.1 ± 0.62	90.7 ± 2.11	13.82 ± 0.21
F		6+	27	59.5 ± 0.50	90.9 ± 2.82	14.18 ± 0.15
All Non-menstruating Girls .. .			144	59.9 ± 0.24	93.3 ± 1.30	14.07 ± 0.07
F	Yes	1	41	61.3 ± 0.38	112.8 ± 3.41	13.79 ± 0.10
F		2	136	62.0 ± 0.18	116.2 ± 1.74	13.88 ± 0.08
F		3	120	61.6 ± 0.21	113.3 ± 1.65	13.86 ± 0.08
F		4	65	61.8 ± 0.27	112.8 ± 2.29	13.88 ± 0.13
F		5	39	61.3 ± 0.31	108.2 ± 2.28	13.78 ± 0.05
F		6+	75	61.4 ± 0.26	110.1 ± 1.79	13.84 ± 0.15
All Menstruating Girls			476	61.7 ± 0.10	113.1 ± 0.85	13.85 ± 0.05

showed no evidence of significant differences. Analysis of the data for the non-menstruating girls showed that regression of haemoglobin level on height and weight is significant, and neither the regressions nor the adjusted mean haemoglobin levels in the six subgroups differ significantly. As a significant overall regression was not found in the menstruating girls, height and weight were ignored and the mean haemoglobin levels of the subgroups were compared by an analysis of variance. This showed that significant differences between mean haemoglobin levels did not occur. It therefore appears that, although there is evidence of some inconsistency in the boys, family size in relation to haemoglobin level can be ignored in these data, provided that, at least in boys and in non-menstruating girls, the effects of differences in mean height and weight are considered.

Further examination of the data showed that the proportion of the total sum of squared deviations which can be "explained" by height alone, independently of the effect of weight, is not significant in any of the main groups. Therefore, in this context height can be ignored, and the haemoglobin level in the boys can best be described by the regression equation:

$$y = 12.79 + 0.0150x$$

where y is the haemoglobin level in g.Hb and x is the weight in pounds.

The correlation coefficient (r) is 0.32 and the standard deviation from regression (s) is 0.95 g.Hb.

In the non-menstruating girls (using the same symbols) the equation is:

$$y = 13.09 + 0.0106x$$

where $r = 0.21$ and $s = 0.78$ g.Hb.

In the menstruating girls reference to weight is unnecessary, and in these the mean level is 13.85 ± 0.05 g.Hb.

Comparison of the mean haemoglobin levels in the boys, and in the non-menstruating and menstruating girls, corrected to a common mean weight, is difficult, as the regression coefficients in these three main groups differ significantly ($0.01 > P > 0.001$). However, the regression coefficients for boys and non-menstruating girls do not differ significantly, and a regression analysis of these two groups show that the boys have a significantly higher mean haemoglobin level than the non-menstruating girls by 0.13 g.Hb, weight held constant. Likewise, the regressions for non-menstruating and menstruating girls do not differ significantly and the mean haemoglobin level of the non-menstruating girls is significantly higher than that of the menstruating girls by 0.33 g.Hb, weight held constant.

In view of the positive skewness shown in the distribution of weight in the three main groups of children (Table II), the effect of transforming each weight to its cube root was tested in several subgroups. In no case did this transformation alter the significance of regression and only extremely small changes were caused in the sum of the squared deviations of haemoglobin due to regression.

DISCUSSION

The data presented here do not suggest that anaemia is a serious problem in school children in Cardiff. A few children did in fact have haemoglobin levels below the level suggested as the criterion of anaemia by the World Health Organization (1959), but, as pointed out by Elwood (1964), the use of a single level of haemoglobin to discriminate "anaemic" from "non-anaemic" subjects, will only identify a group some of whose members will have a low haemoglobin level because of iron deficiency or other cause and others because they represent the lower tail of the distribution of haemoglobin levels in subjects who are "normal" and not iron deficient. These latter are likely to predominate in any group of "anaemic" subjects, so defined, if, like the main groups in the present study, this is drawn from a population in which the distribution of haemoglobin levels is symmetrical. In fact, if normal curves are fitted to the present data, the numbers expected with haemoglobin levels below 12 g.Hb in boys and in menstruating girls are 3·96 and 17·19 respectively, which are very close to the observed numbers of 4 and 19 respectively.

The data suggest that there is a significant association between haemoglobin level and weight in boys and in non-menstruating girls, but there is no evidence of such an association in girls who have started to menstruate. The effect of weight is small, though there is some evidence that it is more marked in boys than in non-menstruating girls (this difference is not significant). Height, independent of weight, does not appear to be significantly associated with haemoglobin level.

The fact that the association is shown by non-menstruating but not by menstruating girls is of interest. It is possible that some members of a group of female subjects, such as the one examined here, may show haemoglobin levels which, because of variation within the menstrual cycle, may differ from their "true" levels, and such variation, if uncontrolled, may be sufficient to obscure an association between haemoglobin level and another variate such as weight, particularly if the association is weak. No recent workers appear to have examined this source of variation in haemoglobin level, and although some early workers failed to find evidence of cyclical fluctuations, Duckles and Elvehjem (1937) and Leichsenring, Donleson, and Wall (1941) did in fact find that the mean haemoglobin level of women varied during the menstrual cycle. They respectively stated the maximum mean fluctuation in the groups they examined as 0·94 and 0·19 g.Hb. Their data have

been re-examined by the present authors in an attempt to ascertain the difference between mean haemoglobin level of a group of women investigated without reference to menstrual cycle, and the mean level of the group, had each woman been investigated during the phase of her menstrual cycle when her haemoglobin level was at its maximum. This re-examination suggests that the mean of a group taken at random with respect to the menstrual cycle of each, as were the menstruating girls in the present study, may understate the "true" level by between 0·22 (using the data of Duckles and Elvehjem, 1937) and 0·11 g.Hb (using the data of Leichsenring and others, 1941). Such an effect may be relevant to the comparison made here between menstruating and non-menstruating girls. The difference between them in mean haemoglobin, when corrected for difference in mean weight, is about 0·33 g.Hb, but it may be that the true difference, independent of the effect of cyclical menstrual changes, is between 0·1 and 0·2 g.Hb. The difference may therefore be similar in size to that between the boys and the non-menstruating girls which, when corrected for a difference in mean weight, is about 0·13 g.Hb.

The differences in mean haemoglobin which remain after removal of the effect of weight and the possible effect of menstruation are of considerable interest. Leichsenring and others (1941) found a significant difference ($P < 0\cdot01$) in the mean haemoglobin level of thirteen high school girls who had not menstruated and 33 of the same age who had, and they also found that the mean haemoglobin level appeared to fall for 2 or 3 years after the onset of menstruation and then to rise again, though in these data they confused age with number of years since onset of menstruation. They suggested that these trends were more likely to be due to differing rates of growth than to quantitative differences in menstrual iron losses.

The present data appear to agree with these conclusions, for it seems unlikely that menstrual iron losses before the age of 14 years could have been sufficient to account for much, if any, of the differences between the groups of girls examined here. While differences in mean weight do not appear to account for the total differences in mean haemoglobin level between any of the three main groups examined, it may be that some other aspect of body mass (such as muscle mass) might have done so, either alone or together with some measure of the growth rate.

SUMMARY

504 boys and 620 girls, all aged 14 years, were seen at the routine school medical examinations in

eleven Cardiff schools. Height and weight were measured, family size and whether each girl had started to menstruate were recorded, and the haemoglobin level of each was estimated (as g.Hb) from finger-prick blood.

The distributions of haemoglobin level in the boys, and non-menstruating and menstruating girls were examined. These do not suggest that anaemia, as usually defined, is a serious problem in these children.

A significant association between haemoglobin level and weight was found in the boys and in the non-menstruating girls, but not in the menstruating girls. Height showed no independent significant association with haemoglobin level, nor did family size, independent of the effect of weight. The difference in mean haemoglobin level, weight held constant, in boys and non-menstruating girls was about 0.13 g.Hb, and in non-menstruating girls and menstruating girls about 0.33 g.Hb. It is suggested that differences in the rate of growth or some such factor may account for much of these differences,

though some of the difference between the two groups of girls may simply be due to cyclical fluctuations in haemoglobin level during the menstrual cycle.

Many people gave invaluable help with this study. In particular, we wish to thank Prof. A. L. Cochrane and Prof. H. Scarborough for advice and encouragement, Mrs P. Figgins for the field work and haemoglobinometry, and the school nurses of the Cardiff Public Health Department for willing help with the field work.

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