AN ANTHROPOMETRIC STUDY OF EDINBURGH SCHOOLCHILDREN

PART II: COMMENTS ON RESULTS

BY

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In Part I of this paper (Provis and Ellis, 1955), a description was given of the measurements of more than 1,700 Edinburgh schoolchildren in 1952-53, these children being a stratified sample of the whole school population. Tables 1 and 2 in that paper summarized the various measurements and indices according to age group and sex, and Figs. 1 to 4 illustrated the age-group means for three linear measurements and two measures of width.

Though group means do not describe the individual child's increments or growth pattern with age, the group means together with the variability of measurements of the individual children in each group give an indication of the range of 'normal' measurements at different ages. It seems worth while, therefore, to make some comments on the points of special interest in the measurements of Edinburgh children, especially as cross-sectional surveys of British schoolchildren have in the main been limited to measurement of height and weight, and very few data on body widths or on head measurements are available. The results which were tabulated in Tables 1 and 2 in Part I are discussed in more detail in the paragraphs which follow, and some additional diagrams are given, these being numbered Figs. 5 to 9 to form a sequence with the diagrams shown in Part I.

Length Measurements

Total Crown-Heel Length. The mean lengths and standard deviations for each year-group of boys and girls from 5 to 17 years were shown in Tables 1 and 2 (Part I). From ages 5 to 10 years there was little difference in the group means for boys as compared with girls, and for both sexes the increase with age was approximately linear. From the age of 10+ years, the girls' means began to overtake and exceed those of the boys. Though the differences were small they were consistent and continued until the

age of 13+. From 14+ years onwards the boys' means continued to increase linearly whilst the increase in girls' means flattened out, so that each year the greater mean length for groups of boys became more marked.

In the earlier years, when boys' and girls' means were almost the same, the regression estimates were as follows:

Age (yr.)	7	8	9	10
Group mean length (cm.)	118.8	123.3	127.8	132.3

The variability of individual children's lengths around the group mean, as indicated by the standard deviation of each mean, can be quickly judged by the coefficient of variation (ratio of standard deviation to group mean). It will be seen in Tables 1 and 2 (Part I) that the coefficients of variation of length were relatively low and ranged mainly around 4% to 5%. That is to say, if two standard deviations on either side of the mean are taken as the main range which includes approximately 95% of the observations, the great majority of the children in each age-group had lengths within 10% of the group mean length.

Stem Length. The group means for stem length were consistently higher for boys than for girls until the age of approximately 11 years. From ages 11 to 15 the group means for girls increased rapidly, and at 12 and 13 years the girls' means considerably exceeded those of the boys. From age 15 onwards, however, the boys' group means again overtook those of the girls and increased rapidly, so that at ages 16 and 17 the mean stem lengths for groups of boys were far greater than those for groups of girls. The pattern of increase of group mean stem length with age was to some extent similar for the two sexes in that, for both there was

at first an approximately linear increase, then an acceleration and more rapid rate of increase and finally a deceleration and flattening out. In girls' means the accelerated rate of increase began at about 10+ years, nearly three years earlier than in boys' means which did not exhibit the accelerated rate of increase until about 13+ years. Similarly, the flattening out and slower rate of increase began earlier in girls' group means than in boys'.

In the first few years, when increase in group means was fairly steady, the regressions gave the following estimates:

Age (yr.)	6	7	8
Group mean stem length (cm.):			
Boys	64	66	68
Girls	63.5	65.5	67.5

The variability of individual children's stem length in relation to the group mean, as indicated by the coefficient of variation, was very similar to the variability of crown-heel length, though perhaps very slightly lower. At ages up to 13 years the coefficient of variation approached 5%; for boys from 14 to 16½ years the variability increased a little.

Span. The group mean span for boys up to the age of 12 years or so was consistently a little higher than for girls. At ages 12 and 13 the girls' means approached and even overtook those of the boys, but from 14 years and onwards the group means for boys rose considerably higher than for girls and the differences increased progressively. The pattern of increase of group mean span for boys was almost linear throughout the age range from 5 to 16 years. For girls' means the pattern was one of almost linear increase up to the age of 13, and then a flattening out for 14-year-olds and onwards.

In the middle period of 10 to 12 years, when the group means for boys were only a little greater than for girls, the regressions gave the following estimates for boys' mean span:

Age (yr.)	10	11	12
Group mean span (cm.) ..	133.5	139.0	144.5

The variability of the span of individual children relative to the mean for each age-sex group, as shown by the coefficient of variation, was very similar to the variability of total length and very slightly greater than that of stem length. As with the latter, so with span the variability of individual boys' measurements at ages 14 to 16 years was a little greater than for girls or for younger boys.

Relationships between Lengths

Ratio of Stem Length to Total Length. The proportion which stem length forms of total length is known to vary with age and relative growth rate. Fig. 5 illustrates the changes in ratio of stem length to crown-heel length for groups of boys and girls of different age. Though the group mean ratios for both sexes varied only between 0.58 and 0.52, within that range an age pattern was clearly discernible. Both for boys and for girls, the mean ratio fell during the earlier years, stabilized during the period of puberty, and rose very slightly in the oldest age groups. The difference between the sexes, however, is apparent. For age groups under 11 years the group means for girls were consistently a little lower than those for boys, whilst for age groups over 11 years the girls' ratios were markedly higher than the boys'. The patterns seem to confirm the earlier onset of puberty in girls and their greater relative stem length than leg length during this period.

From the data obtained in this study, the boys' means formed a more regular pattern than those of the girls. This was found also in most of the other measurements taken in this investigation. Whether this is due to greater variability in girls' measurements or whether it is partly due to less successful measuring of female subjects is a matter for speculation.

Ratio of Span to Total Length. Fig. 6 shows the changes in the mean ratio of span to length with changing age. As might be expected, the ratio for both sexes lay very close to unity, the range being from 0.97 to 1.02. Again the pattern for boys was more clearly apparent than that for girls, but for both sexes the mean ratio rose sharply for the youngest age groups, and more slowly from 9 years or so. The mean ratio for girls was consistently less than that for boys; for the latter the group mean reached 1 at about 8½ years, whilst for girls the ratio did not reach 1 until nearly 12 years.

Width Measurements

Biacromial Diameter. From a scrutiny of Tables 1 and 2 (Part I) it is apparent that the group means of biacromial diameter for boys and girls of similar age were very similar until the age of approximately 11 years. For age groups from 5 to 11 years the group means rose fairly steadily, and for boys a similar rate of increase continued until about 14½ years. For girls, however, there was a more rapid increase in the means from 11½ to 13½ years, and then a marked flattening out in the rate of increase

FIG. 5.—Stratified sample of Edinburgh school-children. Relationship between stem length and total length by age and sex.

FIG. 6.—Stratified sample of Edinburgh school-children. Relationship between span and total length by age and sex.

from 14 years onwards. Thus, for age groups from $11\frac{1}{2}$ to nearly 14 years the mean biacromial diameters for girls consistently exceeded those for boys. From $14\frac{1}{2}$ years onwards the boys' means rose at a much steeper rate than in the earlier years, so that the excess of boys' means over girls' increased rapidly.

During the middle years, when the means for the

two sexes were very similar, the estimated values were as follows:

Age (yr.)	9	10	11
Group mean biacromial diameter (cm.)	28	29	30

The variability of biacromial diameter within

each age-sex group (as indicated by the coefficient of variation) was between $3\frac{1}{2}\%$ and 6% for ages up to 9 years and a little greater at ages above 9 years. For the age groups 14 to $16\frac{1}{2}$ years the variability of biacromial diameters among boys was rather greater.

Pelvic Width. As seen in Tables 1 and 2 (Part I) and Figs. 3 and 4, the mean intraspinal pelvic width for groups of boys and girls rose throughout almost the entire age range. From 5 years until 11+ years, the boys' means were a little greater than the girls', and the increase for both sexes was almost linear. From 11+ to 15 years the rate of increase of girls' means accelerated, and during these years the mean pelvic width of girls exceeded that of boys. From 15 years or so onwards, the rate of increase of boys' means accelerated slightly while for girls it slowed down.

At ages 9 to 11 years, when the mean pelvic width for boys and girls was very similar, the regressions indicated the following estimates:

Age (yr.) ..	9	10	11
Group mean pelvic width (cm.):			
Boys	21.0	21.7	22.4
Girls	20.8	21.5	22.2

The variability of individual children's pelvic width around the group mean was a little higher than the variability of length, and the standard deviations ranged mainly from 5% to 7% of the corresponding means. The greatest variability for both boys and girls appeared to be in the ages 12 to 15 years.

Weight

Tables 1 and 2 (Part I) and Fig. 7 below show that the mean weights for each age-group increased curvilinearly until 15+ years and thereafter increased less rapidly. From ages 5 to 10 the means for boys and girls were very similar, those for boys being perhaps very slightly greater. From 11 to 14 years the rate of increase of girls' means became steeper, and the excess of the girls' means over the boys' was most marked at ages 12+ to 13+ years. From 13+ years onwards the increase of the girls' means was less rapid while the boys' means increased more steeply, so that from 15 years onwards the group means for boys were considerably greater than the means for corresponding groups of girls.

In the middle period, 8 to 11 years, when the means for the two sexes were closest to each other, the regression for boys gave the following estimates:

Age (yr.) ..	8	9	10	11
Group mean weight for boys (kg.) ..	23.7	25.9	28.6	31.8

The variability of weights of individual children around the group means was considerable even in the youngest age groups and increased with age until 13 to 14 years. Even at ages 5 to 9 years the coefficients of variation ranged from 10% to 16%; that is to say, the majority of the children had weights within the range of 20% to 32% on either side of the group mean weight. At ages 12+ to 15+ years the coefficients of variation ranged from 15% to 19%, indicating even wider divergence of individual weights from group means.

Head Measurements

Length, Breadth, Circumference. For all three measurements the group means rose fairly steadily with age, the rise being almost linear for head breadth; and for all three measurements the boys' means were consistently greater than the means for groups of girls of similar age. Fig. 8 illustrates one of the head measurements, namely the increase of mean head length with age. The regressions gave the following estimated measurements:

Age (yr.) ..	8	9	10
Group mean head length (cm.):			
Boys	18.11	18.20	18.29
Girls	17.74	17.83	17.92
Group mean head breadth (cm.):			
Boys	14.22	14.30	14.38
Girls	13.93	14.01	14.09
Group mean head circumference (cm.):			
Boys	52.25	52.55	52.85
Girls	51.62	51.92	52.22

The variability of individual children's head measurements in relation to the group means was somewhat lower than the variability of body lengths and considerably lower than the variability of weight. For head length and breadth the coefficient of variation was between 2% and $4\frac{1}{2}\%$, and for head circumference the coefficient was between 2% and $3\frac{1}{2}\%$. In contrast with body lengths and weight, for the various head measurements there appeared to be no association of variability with age.

Ratio of Breadth to Length (Cephalic Index).

Though for each of the separate head measurements the age group means formed very consistent patterns, the ratio of breadth to length of head of each individual child gave no pattern at all, nor was any regularity discernible in the age-group means of this ratio. For both sexes, the group means of head-breadth/length ratio ranged in the main between 0.782 and 0.793—a very narrow range within which it was difficult to perceive any consistent trends. Fig. 9 illustrates the means of the ratios for each

FIG. 7.—Stratified sample of Edinburgh school-children. Mean weight, by age and sex.

FIG. 8.—Stratified sample of Edinburgh schoolchildren. Mean head length, by age and sex.

FIG. 9.—Stratified sample of Edinburgh school-children. Relationship between head breadth and head length (cephalic index), by age and sex.

age-sex group; also drawn in Fig. 9 are the 'best-fitting' linear trends of mean cephalic index with age. (Though these lines give very poor summary descriptions of age-trends owing to the relatively wide and irregular scatter of the age-group means, no curve would give any better description.) It will be seen in Fig. 9 that both the male and the female summarizing trends gave a slight positive slope of mean cephalic index with age. On the whole the mean cephalic index for groups of girls was a little higher than for groups of boys.

It is possible that the fluctuations in mean cephalic index reflect lack of precision in measurement rather than age changes in the head-breadth/length relationship; it must be remembered that measurements were made to the nearest half-centimetre, using a Collins pelvimeter. The data obtained in this cross-sectional study cannot give inferences about longitudinal growth patterns. The linear trends, however, do not support the conclusion drawn by Cawley, Waterhouse and Hogben (1949) that the mean cephalic index decreases with age in a male population and that before the age of 12 years a female population is on the average more dolichocephalic than a male population.

Discussion

The results obtained in this investigation agree in the main with the findings of other investigators. But for certain characters, notably biacromial

diameter and pelvic width, the findings in the present study are markedly different from those of Hogben, Waterhouse and Hogben (1948). In the latter study the mean biacromial widths for groups of boys were considerably lower than those found in groups of Edinburgh boys of similar age (differences ranging from $3\frac{1}{2}$ cm. at age $9\frac{1}{2}$ years to $5\frac{1}{2}$ cm. at $15\frac{1}{2}$); and the means for groups of girls were about 1 cm. lower than for Edinburgh girls of similar age. Moreover, the finding that 'the mean absolute shoulder width of the girl is greater than that of the male, and there is no sharp divergence associated with puberty' was not borne out in the Edinburgh results. Though there might be several explanations for the differences between the means recorded by Hogben *et al.* and those found in Edinburgh, the different male/female relationships cannot be easily explained. Even more markedly different are the findings of Hogben *et al.* in respect of pelvic width; their conclusion was that 'until the thirteenth year, there is no consistent difference between the mean pelvic width of the girls and boys of our sample. Thenceforward, in each age group, the absolute mean of the hip width of the female is greater than that of the male of the same age.' In the Edinburgh groups the mean pelvic width was greater for boys than for girls up to the age of $11\frac{1}{2}$ years; from 12 to $15\frac{1}{2}$ years the means for girls were greater than those for boys, but from 16 years and onwards the means for boys were again greater than those for girls.

These measurements are of course no guide to the pattern of growth of the individual child. Group means may and often do suggest a steady rate of growth from year to year, yet individuals within the group may be well below the average in one year and well above in the following year. Only longitudinal studies would provide the data to indicate how often a child of average weight or height at one age continues in succeeding years to be of average weight or height, and how often an individual child's growth fluctuates widely from above to below the group average year by year.

It is interesting to observe the similarity between the coefficients of variation of total length, stem length, span, biacromial diameter and pelvic width—a similarity not only in the magnitude of the coefficients of variation but in their age pattern. The much greater variability of weights of individual children and the more marked age trends in such variability are to be expected. By contrast, the low variability of head measurements and the lack of any age trend in variability is worthy of note; it is presumably attributable to the fact that most of the head growth has already occurred before the age of 5 years.

Two further points of interest seem worthy of comment. First, reference has already been made to the possibility that the measuring of female subjects by male investigators might be less consistent than the measuring of male subjects. This is a point to bear in mind when considering the irregularity in the pattern formed by the mean measurements of groups of girls; moreover, it might repay further investigation in future studies. Secondly, in analysing the data obtained in this study it was observed that all the measurements taken with the Collins pelvimeter (to the nearest half-centimetre) showed a marked bias for the whole-centimetre measurements as compared with the half-centimetre measurements. In the frequency distributions the whole-centimetre measurements were nearly four times as common as the half-centimetre measurements. Needless to say, corrections were made in the analysis to compensate for this bias; but future investigations might guard against the possibility of such bias.

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