

GROWTH OF THE SKULL IN YOUNG CHILDREN PART I: STANDARDS OF HEAD CIRCUMFERENCE

BY

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In adults only gross pathological lesions cause an increase in size of the head, but in children enlargement due to slowly growing intracranial lesions must be distinguished from the changes which accompany normal growth. Hence the clinical importance of establishing "normal" increments for each phase of the growing period.

The following contribution to the subject of head size is based on serial measurements of the head circumference of 331 boys and 333 girls who attended the Oxford Child Health Survey between 1944 and 1954.* These children were seen five times during their first year and thereafter at six-monthly intervals until they reached the age of 5 years. An additional appointment at 7 years of age was obtained in nearly 400 cases. In the following account all measurements for the period 1 to 12 months were taken within 14 days of the stated age; from 1 to 5 years they were taken within one month and at 7 years within two months. Failure to reach the age of 7 by 1954, and missed or incorrectly dated appointments account for the different numbers examined at each age and each interval (Tables I and II). The shortest sequence of correctly dated measurements was four and the longest 14. The head circumferences were measured by placing the tape on the supra-orbital margins and carrying it horizontally round the most prominent part of the occiput.

Results

At each of the 14 ages represented in the survey the mean values for boys of the head circumference was a fraction larger than the mean value for girls

* The aims and methods of this survey have already been described (Stewart and Russell, 1952) and an up-to-date list of published papers is available in the bibliography of a recent report (Acheson, Kemp, and Parfitt, 1955). Twins were not included but 102 families were represented by two or more sibs. The children were drawn from all levels of society in Oxford but compared with the country as a whole their standard of living was above average (Barber and Blaschko, 1954). Growth changes in the pituitary fossa and anterior fontanelle have formed the subjects of previous papers (Acheson, 1954; Acheson and Jefferson, 1954). Though the survey officially ceased in 1954 a number of children still remain under observation. It is hoped that the serial measurements of head circumference will eventually be available for the age period 7 to 15 years.

TABLE I
HEAD CIRCUMFERENCE FOR BOYS AND GIRLS DURING
THE FIRST SEVEN YEARS OF LIFE

Age	Boys			Girls		
	Number	Mean (cm.)	S.D.	Number	Mean (cm.)	S.D.
1 month	295	37.3	±1.54	282	36.5	±1.41
3 "	229	40.7	±1.43	230	39.8	±1.39
6 "	275	43.6	±1.45	262	42.5	±1.42
9 "	247	45.7	±1.40	259	44.6	±1.41
1 year	289	46.8	±1.40	275	45.6	±1.22
1½ "	255	47.9	±1.40	255	47.0	±1.30
2 "	264	49.1	±1.47	260	48.0	±1.32
2½ "	219	49.8	±1.39	221	48.8	±1.35
3 "	216	50.4	±1.35	227	49.5	±1.35
3½ "	226	51.0	±1.40	222	50.1	±1.45
4 "	233	51.2	±1.41	229	50.7	±1.46
4½ "	220	51.6	±1.45	217	51.0	±1.48
5 "	224	51.8	±1.47	225	51.2	±1.50
7 "	187	52.7	±1.48	194	52.2	±1.37

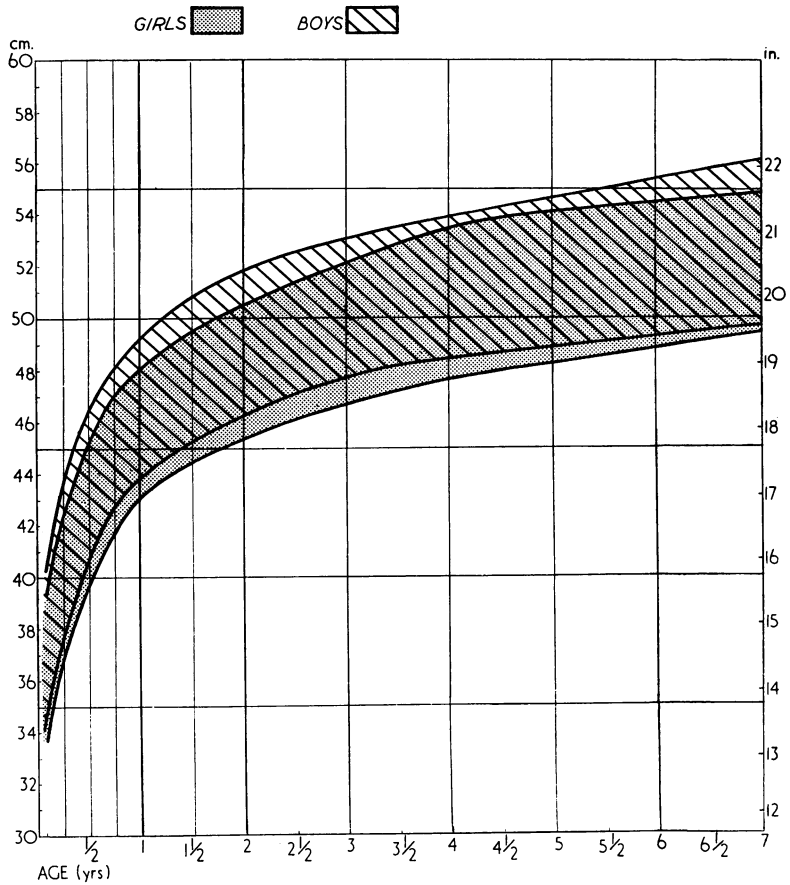
(Table I). Though invariably slight this difference was greater before the age of 3 (range 1.17 to 0.79 cm.) than after (range 0.85 to 0.45 cm.). That is to say the boys, as usual, began by growing faster than the girls and ended by growing more slowly but at no time did they lose their initial lead. Table II shows the actual increase in head circumference achieved during the period of maximum growth, i.e., 1 month to 3 years. In Table II the sexes are not distinguished but in addition to the means and standard deviations for successive periods, a set of figures is given which indicate the upper limit of "normal" increment. Each of these upper limits represents the mean plus the standard

TABLE II
INCREMENTS OF HEAD CIRCUMFERENCE IN FIRST
THREE YEARS OF LIFE (BOYS AND GIRLS COMBINED)

Age Period	Number	Mean (cm.)	S.D.	Upper Limit for "Normal" Increments (cm.)
1-3 months	390	3.4	±1.21	5.7
3-6 "	427	3.2	±1.04	5.2
6-12 "	457	3.2	±1.15	5.4
12-18 "	442	1.5	±0.81	3.1
18-24 "	470	1.2	±0.76	2.7
24-30 "	412	0.9	±0.69	2.3
30-36 "	397	0.8	±0.67	2.2

deviation multiplied by 1.96 and thus includes nearly all the original measurements. It will be seen that the rate of growth fell rapidly at first and then more slowly, so that what was "normal" for the first two months of observation was also "normal" for the next three months, for the next six months, and for the last 18 months.

Besides revealing a remarkably even progression of the means, Table I shows that the observed variation of the individual measurements was virtually the same in each of the 28 groups defined by age and sex. These two features of the records can be more clearly visualized in the Figure, where provisional ranges of "normal" growth are depicted for the two sexes. In this diagram the records for boys and girls have been superimposed so that the upper margins of the shaded zones represent the lines drawn between serial values of the mean head circumference plus their standard deviations multiplied by 1.96 ($M + 1.96\sigma$) and the lower margins the lines between serial means minus 1.96 σ . In this way the two channels of "normal" growth cover all but 5% of the original measurements. It will be seen that for both sexes 80% of the total growth between 1 month and 7 years was usually achieved by the age of 30 months.



FIGURE—Normal channel of growth of head circumference. (Mean \pm 1.96 σ .)

Comparison with Other Published Standards for British Children

Until 1952 standards of head size for British children appear to have been based not on serial measurements of the same children, but on single measurements of children of different ages. The largest series of such head circumferences describes 1,400 children seen at a children's hospital in London (Myers, 1926). Means and ranges for successive age periods are given and the author states that some of the children were measured more than once. The two sexes are distinguished in the Table but the actual number of records is not

stated. When plotted in sequence Myer's figures produce an uneven curve, and after the age of 2½ the children he examined appear to have distinctly smaller heads than the Oxford children.

Textbooks of children's diseases often include a table of "normal" head circumference for different ages (Pearson and Wyllie, 1935; Paterson, 1944; Sheldon, 1951; Grulee and Eley, 1952; Moncrieff and Evans, 1953). It is frequently impossible to discover on what these standards are based, but they all have one thing in common: when plotted as growth curves they yield an uneven sequence, thus betraying the fact that they are not based on serial measurements of the same children.

The first longitudinal growth study of British children of pre-school age was published in 1952 (Low). This describes 66 boys and 60 girls, born in Aberdeen between 1923 and 1927, and measured at yearly intervals during the period 3 days to 5 years. At all ages these children were lighter,

shorter, and had smaller heads than the Oxford children. Nevertheless the sex differences in head circumference, the smoothness and general shape of the head growth curves, and the range of variation in the individual measurements are strictly comparable in the two series. It is a moot point whether the differences in absolute size are racial in origin, or whether they are due to secular changes in body size (Clements, 1953), or to different standards of nutrition.

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PART II: CHANGES IN HEAD SHAPE

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In Part I the increase in head circumference which occurs during the first seven years of life is described; Part II is based on the same children and compares the contributions made by growth in the transverse and longitudinal diameters to the overall increase in head circumference.

The "transverse skull diameters" correspond to caliper readings of the maximum distance between the parietal eminences, and the "longitudinal diameters" to caliper readings of the maximum distance between the frontal and occipital eminences. These two measurements were taken five times during the first year, and thereafter at six-monthly

intervals to the age of 5 with one additional measurement at 7 years. On average, just under 300 children of each sex were measured at each age.

Mean values for the transverse and longitudinal diameters by sex and age are shown in Table I and Fig. 1. In both diameters and at each age the boys' heads were significantly larger than the girls', but the mean differences never exceeded 0.5 cm. and the total increments for the whole seven-year period were virtually identical in the two sexes. (The boys actually gained 1 mm. less in the transverse and 1 mm. more in the antero-posterior diameter.) In both sexes, but particularly in girls,

TABLE

MEAN TRANSVERSE AND LONGITUDINAL SKULL DIAMETERS AND CEPHALIC INDICES OF OXFORD BOYS AND GIRLS AGED 1 MONTH TO 7 YEARS

Age	Boys						Girls					
	No.	Transverse		Longitudinal		Cephalic Index	No.	Transverse		Longitudinal		Cephalic Index
		Mean (cm.)	S.D.	Mean (cm.)	S.D.			Mean (cm.)	S.D.	Mean (cm.)	S.D.	
1 month	297	10.2	±0.62	13.0	±0.80	78.6	299	9.8	±0.54	12.7	±0.76	77.5
3 months	308	11.0	±0.49	13.9	±0.71	79.5	307	10.9	±0.53	13.7	±0.77	79.8
6 "	310	12.0	±0.64	14.8	±0.77	81.3	317	11.8	±0.56	14.7	±0.81	80.4
9 "	284	12.6	±0.59	15.5	±0.69	81.3	298	12.4	±0.59	15.4	±0.78	80.8
12 "	332	12.9	±0.58	16.0	±0.75	80.9	331	12.8	±0.54	15.9	±0.83	80.5
1½ years	318	13.2	±0.58	16.6	±0.70	79.6	329	13.0	±0.54	16.3	±0.68	79.8
2 "	328	13.5	±0.59	17.0	±0.72	79.5	325	13.2	±0.51	16.7	±0.66	79.2
2½ "	283	13.8	±0.55	17.3	±0.69	79.8	295	13.5	±0.51	16.9	±0.69	79.6
3 "	281	13.8	±0.56	17.3	±0.70	79.6	290	13.6	±0.53	17.0	±0.65	80.0
3½ "	268	13.9	±0.57	17.6	±0.65	79.1	272	13.7	±0.53	17.2	±0.59	79.6
4 "	269	14.0	±0.56	17.7	±0.62	79.1	267	13.8	±0.50	17.3	±0.60	79.6
4½ "	250	14.1	±0.54	17.9	±0.60	78.8	256	13.9	±0.51	17.4	±0.60	79.6
5 "	260	14.1	±0.56	18.0	±0.59	78.7	265	13.9	±0.52	17.5	±0.58	79.3
7 "	186	14.4	±0.55	18.2	±0.61	79.4	199	14.1	±0.53	17.8	±0.63	79.6