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GROWTH FROM THREE TO FIVE YEARS

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Current British literature contains few studies of the growth of pre-school children. The recent publication of half-yearly weights and heights by Acheson, Kemp, Parfit, Jefferson, Mynors, and Hewitt (1955) and the more detailed investigation of Hammond (1955) are the main features of current literature. The tables of Low (1952), though of recent publication, are derived from a longitudinal study of children born between the years 1923 and 1927. Before the first-mentioned publication we were dependent upon the work of Gore and Palmer (1949) in Britain and of various American investigators, notably Simmonds (1944), for our standards of weights and heights of pre-school children.

The present paper gives the results of an investigation into growth of children aged from 3 to 5 years.

Material and Methods

The observations were recorded on 947 male and 971 female children born in the Simpson Memorial Maternity Pavilion of the Royal Infirmary, Edinburgh. Multiple births were excluded, as were also children with a congenital malformation, or whose growth had been retarded by serious illness. Premature or post-mature children were excluded, no child being included who weighed less than 5½ lb. or more than 9 lb. at birth.

Children were weighed in vest, pants, and socks, on a beam balance to the last complete quarter-pound and 4 oz. were deducted for clothing. The supine crown-heel and crown-rump lengths were ascertained to the last complete millimetre on a measuring board of the type previously used (Thomson, 1956a). While the child was on the measuring board the intercristal pelvic width was measured to the last complete millimetre by using obstetrical callipers in conjunction with the steel millimetre scale incorporated in the board. The head circumference was measured over the most prominent portions of the occipital and frontal bones on a millimetre linen tape. The tape was checked frequently against the steel millimetre scale and replaced when a discrepancy was found.

The investigation was mainly cross-sectional, and children were examined within 7 days of the third, fourth, and fifth birthday. and at intervening quarters.

Results

Means and standard deviations for the five measurements are given in the Appendix. The only recent British work with which comparison can be made is that of Acheson and others (1955), which gives mean weights and mean heights for Oxford children at 6-month intervals. The mean weights of the Oxford children were greater than those reported here (Table I). They included underclothing, but, even with this advantage, the Oxford means of weight are significantly greater only in the case of males at 4 and 4½ years. Thus one may conclude that, in general, the differences between the mean weights of these two groups of children are not significant.

The mean heights given for the Oxford children are erect heights. After conversion to supine lengths, using Palmer's formula (Palmer, 1932), the differences from the present data are of little importance (Table I, opposite).

Of the American data, those of Simmonds are probably the best for comparison. They appear to represent an optimum standard of growth since, they were:

> "derived from measurements of a selected sample of 999 white children the majority of whose parents are above average both in educational and economic level and who are of North European ancestry."

The mean weights given by Simmonds were approximately 2 to 2½ lbs greater than those now reported (Table I). Much of this difference is represented by clothing, since the American children appear to have been weighed in indoor clothing, the nature of which was not described and for which no allowance was made. The difference between the mean weights tends to increase with age, particularly in females. Since the weight of clothing worn increases with age, this factor must be taken into account when attempting to make a comparison. Nevertheless, it appears probable that the mean weights of the American children are significantly

TABLE I

COMPARISON OF RESULTS WITH THOSE PREVIOUSLY PUBLISHED

(Difference from other results as percentage of means shown in appendix)

Sex			Male					Female				
Age (yrs)			3	3½	4	4½	5	3	3½	4	4½	5
Weight		Acheson and others (1955)	+1·86	+ 2·72	+3·23	+ 3·18	+1·86	+1·91	+ 1·16	+2·95	+ 0·83	+0·73
		Simmonds (1944)	+6·04	+ 6·16	+7·86	+ 7·21	+6·28	+6·54	+ 6·43	+7·17	+ 7·12	+6·76
		Low (1952)	−9·16	—	−8·14	—	−9·92	−3·50	—	−5·12	—	−7·41
		Paton and Findlay (1926) Edinburgh	—	−12·44	—	−10·25	—	—	−10·30	—	−13·86	—
		Paton and Findlay (1926) Rural	—	− 0·47	—	− 2·68	—	—	− 1·83	—	− 5·43	—
Height	Crown-Heel	Acheson and others (1955)	Nil	+ 0·50	+0·29	+ 0·85	+0·09	+0·95	+ 0·41	+0·49	− 0·19	−0·37
		Simmonds (1944)	+1·73	+ 2·11	+2·04	+ 2·72	+2·10	+2·85	+ 2·37	+2·75	+ 2·65	+2·67
		Low (1952)	−4·22	—	−3·90	—	−4·13	−1·49	—	−1·79	—	−2·72
		Paton and Findlay (1926) Edinburgh	—	− 9·15	—	− 8·60	—	—	− 8·23	—	− 7·78	—
		Paton and Findlay (1926) Rural	—	− 1·71	—	− 1·89	—	—	− 5·18	—	− 3·04	—
	Crown-Rump	Simmonds (1944)	−0·37	− 0·01	−0·17	+ 0·55	−0·34	+0·13	− 0·22	+0·20	+ 0·03	+0·23
		Low (1952)	−5·69	—	−5·55	—	−7·23	−4·23	—	−5·83	—	−4·81
Intercristal Width		Simmonds (1944)	+5·5	+ 5·4	+5·2	+ 5·7	+3·9	+6·8	+ 6·4	+5·7	+ 5·1	+4·3
Occipito-Frontal Circumference		Low (1952)	−1·61	—	−1·08	—	−0·94	+0·02	—	+0·50	—	−0·34

greater than the mean weights now published, a view that is supported by the fact that the mean horizontal lengths reported by Simmonds are significantly greater than the supine crown-heel lengths now reported (Table I).

By contrast, there is no significant difference between the mean recumbent stem lengths found by Simmonds and the mean supine crown-rump lengths now reported (Table I). Since the limbs are lateral buds and represent lateral growth, it may be that the significant difference between the mean crown-heel lengths of these two groups of children is due to more rapid growth of the lower limbs in the American group. These differences find expression in the lower mean stem-stature indices* of the Brush Foundation data (Table II).

Further support for this inference is found in the comparison of the intercristal pelvic widths (Table I).

* (Stem Stature Index $= \frac{\text{Crown-Rump Length}}{\text{Crown-Heel Length}} \times 100$)

Here, as with the crown-heel length, the means reported by Simmonds are significantly greater than those reported here. With the exception of the observation in males at 4½ years, there is, with increasing age, a progressive decline in the American excess in intercristal width (Table I).

Comparison with the data of Gray and Ayres (1931) for children of Chicago private schools yields a very similar result.

It is interesting to compare the present data with those of former years, especially if the former data refer to the same country or town, and comparison may be attempted with the observations of Low (1952) and those of Paton and Findlay (1926).

The mean data for weight and crown-rump length now given are all significantly greater than those recorded by Low. The mean supine crown-heel length at 3 years in both sexes is also significantly greater. At 4 and 5 years Low changed from a supine to an erect measurement, and the differences

TABLE II

MEAN STEM-STATURE INDEX

Age (yrs)		3				4				5			
Sex		Male		Female		Male		Female		Male		Female	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Simmonds (1944)		59·6	—	59·4	—	58·5	—	58·1	—	57·4	—	57·0	—
Low (1952)		59·9	1·59	59·2	1·30	58·6	1·50	58·0	1·83	57·3	1·64	57·0	0·93
Wallis (1931)		58·8	1·29	58·4	1·00	57·6	1·22	56·7	1·05	56·4	1·11	55·9	0·96
Present Inquiry	Cross Sectional	60·9	1·60	60·8	1·28	59·8	1·11	59·5	1·13	58·8	1·04	58·4	1·25
	Longitudinal	61·0	1·16	60·7	1·06	59·7	1·19	59·5	0·89	—	—	—	—

at 4 and 5 years have been ascertained after conversion to a supine length, using Palmer's formula (Table I). Their similarity to the difference at 3 years leaves little doubt that these differences are also significant. The mean occipito-frontal circumference now given for males is significantly greater than that given by Low, but by contrast there is no difference between the mean occipito-frontal circumferences for females. To what extent hair growth may be a factor here is an open question. It should be noted that, as in the present inquiry, Low made his observations on urban children.

Among other observations, Paton and Findlay (1926) recorded the mean weight and height at 3+, 4+, and 5+ years of Edinburgh children and the children of agricultural workers. The difference between the present data and those of Paton and Findlay are given in Table I. Comparison with the data of Paton and Findlay are less reliable than with those of Low. The age points are vague (*e.g.* 3+ means over 3 but not yet 4) and on this account 3+ and 4+ are compared with 3½ and 4½ in the present study. The weights reported by Paton and Findlay include indoor clothing, a point which must be noted when considering the amount of the difference shown. The erect heights reported by Paton and Findlay were converted to supine lengths by Palmer's formula before the comparison was made.

The norms of weight and erect height in use in Edinburgh Child Welfare Clinics were prepared by the late Dr. T. Y. Finlay, Maternity and Child Welfare Officer for the City of Edinburgh, when he collaborated with Paton and Findlay. These norms, which are undifferentiated for sex, may be compared with the present data, also undifferentiated for sex, and with Findlay's erect heights converted to supine lengths by Palmer's formula (Table III). This gives a more accurate measure of the change which has taken place in pre-school child growth in Edinburgh during the intervening 30 years.

TABLE III

PERCENTAGE DEFICIT SHOWN BY NORMS IN USE IN CHILD WELFARE CLINICS

City		Edinburgh		Paris			
Sex		Not Differentiated		Male		Female	
Measurement		Weight	Height	Weight	Height	Weight	Height
Age (yrs)	3	− 8·9	− 3·4	− 8·6	− 3·3	− 8·0	− 8·3
	3½	−10·3	− 5·1	− 9·9	− 2·8	− 8·7	− 9·1
	4	−10·2	− 6·0	−10·2	− 2·9	− 8·2	− 9·0
	4½	−11·5	− 6·4	−10·6	− 2·3	− 9·7	− 9·4
	5	−12·2	− 7·0	−11·8	− 2·7	− 9·5	− 9·6

Such findings suggest that comparison with the norms in use in the clinics of another city would be of interest. Graphic norms of weight and height are incorporated in the *Fiche Médicale* used in Paris for children from 2 to 6 years of age. In this instance the sexes are differentiated, but the source of the norms and when they were ascertained is not disclosed. Like the Edinburgh Welfare norms they are less than those now published (Table III). The amount of the difference is so great that, despite the difference in nationality, one suspects that the Paris norms, like the Edinburgh ones, are in need of revision.

The variability from the mean, as measured by the standard deviation, tends to increase with age. This is evident in the Height and Weight Tables of Acheson and others and the Tables of Low and of Simmonds. The trend is also present in this investigation in which the standard deviations are also influenced by the exclusion of children born prematurely and postmaturely.

Because the standard deviation is a measure of variability from a mean which is subject to variation, a longitudinal rather than a cross-sectional investigation might be expected to demonstrate the increasing variability more satisfactorily. Comparison of the standard deviations given in the longitudinal and cross-sectional Tables of Simmonds illustrates this point. It is to be noted however that Low's Tables, though compiled from a longitudinal survey with observations made at the relatively long interval of one year, do not show an increase in variability at every age point. Variability does not appear to have a sex bias. The Tables of Low display no sex bias in the standard deviations and none has been observed in the present inquiry. No sex bias is shown by Simmonds's Tables and, though Acheson and others record greater standard deviations for the heights for males, the contrary is reported by Simmonds.

INFLUENCE OF SEX.—In common with the present findings, most investigators of growth in this age-period report greater mean measurements for males than for females. They include Acheson and others, Simmonds, Paton and Findlay, Gray and Ayres, and Fleming (1933). Some, however (notably Low, 1952, and Hammond, 1955) have reported contrary findings, and whereas in the case of Hammond the small number of observations is probably the explanation, there is no obvious explanation in the case of Low.

The influence of sex in this age-period is not equable, there is a decline in the male excess in all measurements as age increases (Table IV, opposite).

TABLE IV

MALE EXCESS EXPRESSED AS A PERCENTAGE OF FEMALE MEAN

Age (yrs)	Weight	Length: Crown-Heel	Length: Crown-Rump	Occipito-Frontal Circumference	Intercristal Width
3	0·39	0·23	2·03	3·03	2·19
3¼	0·33	0·16	1·78	2·40	2·46
3½	0·29	0·11	1·27	3·13	1·93
3¾	0·19	0·06	0·53	2·29	0·85
4	0·29	0·14	1·78	3·07	1·99
4¼	0·13	0·04	0·07	2·10	1·36
4½	0·10	0·02	0·03	1·44	0·94
4¾	0·13	0·02	0·04	1·96	0·52
5	0·19	0·05	1·07	1·91	1·71

The greatest reduction is in the crown-heel length which at the age of 5 years is virtually the same in males and females. Simmonds also made this observation, which is corroborated by reference to the Tables of Fleming. This finding is not universal and the most outstanding contrary publication is provided by the height norms of the Paris Welfare Clinic record-card, which shows a greater difference between the mean heights of males and females at 5 years than at 3 years. This may be deduced from Table IV, but in considering this table, it must be remembered that these data are the differences between means which are subject to some variation. On this account the general trend of the differences is more important than the individual differences.

Sex influences the mean stem stature index which in general is lower for females than for males (Table II). Few investigators give computations of the mean stem stature index from raw data. Derived from means, Simmonds gave a graphic representation which shows the consistently lower female mean index. Calculations from the raw data on an adequate number of observations were given by Wallis (1931) and by Low, and now in the present data. All agree that females have consistently lower mean indices. In addition, the mean stem-stature index computed from the raw data of forty males and 35 females who were observed at 3 years and 4 years each ± 7 days is given in Table II. This shows a lower mean index for females and confirms that the mean stem-stature index falls with increasing age. It must not be assumed from this, however, that the stem-stature index of the individual child consistently falls with increasing age. Of the forty males and 35 females aforementioned, the index is higher at 4 years for five males (12·5 per cent. and two females (5·7 per cent.). Low gave higher indices at 4 years for nine males (13·6 per cent.) and three females (5 per cent.). The differences between these percentages of the sexes are not of statistical significance, but may reflect the influence of sex.

It is perhaps as well to mention that indices such as this are representative of proportions and throw no light on size and rate of growth. Low and Simmonds both give the same mean stem-stature index for children of the same age (Table II) though the raw data from which the indices are calculated are much lower in the case of Low.

INCREMENTS.—Quite commonly, increments of height and weight are estimated by noting from a Table the difference between means at different age points. Such data, abstracted from cross-sectional Tables, may be less accurate than those taken from longitudinal Tables, but in practice there is very little difference. Simmonds gives both cross-sectional and longitudinal Tables for height.

Ascertainment of the rate of growth by this method lacks an expression of variability of increment. This can only be obtained from analysis of individual increments. Accordingly, the data of the present inquiry were scrutinized for observations made upon children at two consecutive age points. The numbers, though relatively small, are enough to make a computation of quarterly height and weight increments worth while. These are given in Table V, which is cross-sectional.

TABLE V

HEIGHT AND WEIGHT INCREMENTS

Sex ..		Male							Female						
Measurement ..		No. of Children	Weight (oz.)			Length (mm.)			No. of Children	Weight (oz.)			Length (mm.)		
			Mean	S.D.	C.V.	Mean	S.D.	C.V.		Mean	S.D.	C.V.	Mean	S.D.	C.V.
Age (yrs)	3 –3¼	44	16·2	12·2	75·3	19·1	6·0	31·4	33	15·1	8·9	58·9	20·3	8·6	42·4
	3¼–3½	54	20·5	11·7	57·1	18·8	5·2	27·7	49	20·7	14·3	69·1	20·0	5·6	28·0
	3½–3¾	49	16·7	17·1	102·3	18·3	6·4	35·0	62	18·3	14·2	77·6	18·5	5·6	30·3
	3¾–4	44	13·1	11·4	87·0	17·4	5·9	33·9	47	18·9	12·1	64·0	16·2	6·1	37·7
	4 –4¼	38	16·4	11·4	69·5	16·1	5·7	35·4	47	16·1	13·5	83·9	16·7	5·6	33·5
	4¼–4½	30	19·7	12·1	61·4	15·4	6·3	40·9	46	19·4	14·7	75·8	16·6	6·2	37·3
	4½–4¾	42	14·2	12·6	88·7	16·9	4·9	29·0	45	16·4	12·0	73·2	15·9	5·6	35·2
	4¾–5	47	15·7	13·1	83·4	13·8	5·7	41·3	48	15·7	11·2	71·3	15·4	5·8	37·7

The great variability of weight increment disclosed suggests that prediction of weight increment is somewhat hazardous. Indeed, it has been shown (Thomson, 1956b) that a weight measurement at 3 years of age cannot be used to predict what the measurement will be at 4 years of age.

Variation in the crown-heel length increment, is also considerable. It requires approximately ± 70 per cent. of the mean increment to cover 95 per cent. of the observations (Table V). The variability of the crown-heel increment is more uniform than that of weight increment and is much smaller. This is so despite the greater difficulty in measuring length accurately and, in general, inaccuracy increases the variability. It is however, well recognized that length is less affected by environmental factors. This is in keeping with the finding of Robinow (1942), who unfortunately did not distinguish between the sexes. The crown-heel mean increments are of further interest, in that, in both sexes, there is a decline with an increase in age, and with two exceptions, the female mean increment exceeds the male. As with weight, it has been shown that a crown-heel measurement at 3 years bears no relation to the ensuing year's increment. Thomson (1956b).

Summary

(1) Based on 947 sets of observations of males and 971 sets of observations of females, means with standard deviations for weight, supine crown-heel and crown-rump lengths, occipito-frontal circumference, and intercristal pelvic width of Edinburgh children at quarter-year intervals from 3 to 5 years are presented. The observations were made on healthy legitimate singleton children who were neither prematurely not postmaturely born.

(2) The mean measurements in the report are greater than those of Paton and Findlay (1926) or Low (1952), while the mean weights and crown-heel lengths are appreciably greater than the means in use in Edinburgh and Paris Welfare Clinics. This suggests that the Welfare Clinic norms may be in need of revision.

(3) The mean measurements for females are less than the corresponding mean measurements for males. The male excess diminishes with increasing age, until at 5 years in the case of the crown-heel length there is no appreciable difference between the sexes.

(4) The mean stem-stature index for females is consistently lower than that for males even at the age of 5 years, when the crown-heel lenght is approximately the same in both sexes.

(5) The variability of weight increment at quarter-year intervals is greater than the variability of crown-heel increment, despite the greater difficulty in measuring length accurately.

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Appendix Table A

MEAN WEIGHT

Sex..	Male					Female				
Age (yrs)	No. of Children	Mean (lb.)	S.D.	Mean (kg.)	S.D.	No. of Children	Mean (lb.)	S.D.	Mean (kg.)	S.D.
3	109	31·62	3·06	14·34	1·39	101	30·44	3·62	13·81	1·64
3¼	111	32·91	2·53	14·93	1·15	102	31·87	3·48	14·46	1·58
3½	108	33·77	3·33	15·32	1·51	117	32·83	3·64	14·89	1·65
3¾	108	34·41	3·65	15·61	1·65	114	33·78	3·87	15·32	1·76
4	112	35·60	3·82	16·15	1·73	109	34·58	4·04	15·68	1·83
4¼	91	36·36	3·42	16·49	1·55	102	35·90	3·86	16·29	1·75
4½	99	37·74	3·88	17·12	1·76	115	37·37	4·89	16·95	2·22
4¾	99	38·43	4·03	17·43	1·83	103	37·92	4·27	17·20	1·93
5	110	40·26	4·55	18·26	2·07	108	39·49	4·64	17·91	2·11

APPENDIX TABLE B

MEAN LENGTH

Length	Supine Crown-Heel								Crown-Rump							
Sex ..	Male				Female				Male				Female			
Age (yrs)	Mean (in.)	S.D.	Mean (mm.)	S.D.	Mean (in.)	S.D.	Mean (mm.)	S.D.	Mean (in.)	S.D.	Mean (mm.)	S.D.	Mean (in.)	S.D.	Mean (mm.)	S.D.
3	37·78	1·54	959·5	39·2	36·94	1·38	938·3	34·9	22·98	0·91	583·7	23·2	22·52	0·84	572·1	21·3
3¼	38·63	1·33	981·2	33·8	38·01	1·44	965·5	36·4	23·38	0·76	593·9	19·2	22·97	0·86	583·5	21·9
3½	39·16	1·39	994·8	35·4	38·76	1·38	984·4	35·2	23·58	0·75	599·0	19·2	23·29	0·86	591·5	21·9
3¾	39·78	1·55	1010·3	39·5	39·53	1·39	1004·0	35·3	23·79	0·91	604·3	23·2	23·67	0·91	601·1	23·2
4	40·56	1·45	1030·2	36·7	40·01	1·51	1016·2	38·3	24·26	0·87	616·1	22·0	23·83	0·89	605·3	22·5
4¼	41·07	1·55	1043·1	39·5	40·90	1·52	1038·8	38·7	24·35	1·01	618·5	25·7	24·17	0·88	613·9	22·4
4½	41·61	1·73	1056·8	44·0	41·51	1·58	1054·5	40·2	24·63	0·99	625·7	25·2	24·55	0·97	623·6	24·7
4¾	42·30	1·66	1074·4	42·2	42·22	1·46	1072·4	37·1	24·90	0·97	632·4	24·6	24·80	0·91	630·0	23·2
5	43·12	1·79	1095·2	45·6	42·90	1·46	1089·6	37·2	25·33	1·03	643·4	26·2	25·06	0·88	636·6	22·5

APPENDIX TABLE C

MEAN GIRTH

Measurement	Occipito-Frontal Circumference								Intercristal Pelvic Width							
Sex ..	Male				Female				Male				Female			
Age (yrs)	Mean (in.)	S.D.	Mean (mm.)	S.D.	Mean (in.)	S.D.	Mean (mm.)	S.D.	Mean (in.)	S.D.	Mean (mm.)	S.D.	Mean (in.)	S.D.	Mean (mm.)	S.D.
3	19·81	0·48	503·1	12·2	19·22	0·50	488·3	12·8	6·26	0·29	159·0	7·2	6·12	0·33	155·6	8·4
3¼	19·84	0·48	504·0	12·3	19·38	0·54	492·2	13·6	6·40	0·28	162·5	7·2	6·24	0·34	158·6	8·7
3½	19·87	0·47	504·8	12·0	19·27	0·52	489·5	13·1	6·45	0·30	163·9	7·5	6·33	0·33	160·8	8·3
3¾	19·87	0·56	504·7	14·3	19·42	0·48	493·4	12·3	6·51	0·31	165·4	7·9	6·46	0·34	164·0	8·6
4	19·98	0·44	507·4	11·2	19·38	0·51	492·3	13·1	6·67	0·31	169·3	7·9	6·54	0·35	166·0	8·9
4¼	19·95	0·48	506·8	12·1	19·54	0·60	496·4	15·4	6·72	0·32	170·8	8·1	6·63	0·31	168·5	8·0
4½	19·96	0·54	507·0	13·7	19·68	0·52	499·8	13·3	6·80	0·34	172·7	8·7	6·74	0·38	171·1	9·7
4¾	20·06	0·54	509·6	13·7	19·68	0·51	499·8	13·0	6·82	0·33	173·3	8·3	6·79	0·38	172·4	9·7
5	20·15	0·50	511·9	12·6	19·77	0·53	502·3	13·5	7·02	0·34	178·7	8·6	6·92	0·37	175·7	9·5