A LONGITUDINAL STUDY OF THE GROWTH AND DEVELOPMENT OF PREMATURELY AND MATURELY BORN CHILDREN

PART II.—PHYSICAL DEVELOPMENT

BY

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This paper is the second in a series presenting findings in a long-term study of growth and development in a representative sample of nearly 600 premature and maturely born children, delivered in two Edinburgh maternity hospitals in the years 1953 to 1955. The sample, the method of selection, the procedures carried out and the social standards employed have already been described in Part I (Drillien, 1958).

All children in the survey have reached the age of 2 years, and results are now given of the analysis of weight and height measurements, in the first 2 years of life for different birth weight groups in relation to certain genetic and environmental factors. The children were examined at 6, 12, 18 and 24 months of age. At 6 months, infants were weighed on baby scales recording accurately to 1 oz. Thereafter they were weighed on a spring balance type of scale incorporating a seat. These scales are calibrated in ounces up to a weight of 50 lb., but are only considered to be accurate to the nearest 4 oz. Both scales were checked periodically against standard weights. The children were weighed in light indoor clothes, without shoes, and an appropriate deduction made for the clothes still worn. At 2 years old recumbent length without shoes was recorded on a portable measuring board calibrated in centimetres.

Mean Measurements of Weight and Height

Tables 1 to 4 give mean weights, weight increments and standard deviation of these means, at ages 6, 12, 18 and 24 months, for four birth weight groups, of male and female singletons and twins. At each age, mean weight is related to birth weight, the prematurely born showing little tendency to

reduce their initial weight handicap. At 2 years the total weight increment since birth for singletons is highest in the smallest birth weight group. The difference between means of the group $4\frac{1}{2}$ lb. or less at birth, and that over $7\frac{1}{2}$ lb. at birth is 14 oz. for males and 13 oz. for females. The appropriate statistical test shows that a difference of this magnitude is not significant at the 5% point.

In the case of multiple births, the differences in mean weight at 2 years are greater than the differences in mean birth weight, both male and female twins showing smaller weight increments in the lower birth weight groups. Again these differences are not statistically significant.

Table 5 gives mean heights and height increments at 2 years for the same birth weight groups. Here again those who were largest at birth maintain their superiority in height at 2 years, but the height increments for both male and female singletons and twins are greater for those smallest at birth. Here the difference in height increment is statistically significant. There appears to be a definite tendency for those smallest at birth to reduce their height handicap significantly by 2 years of age.

Among singletons, boys show a bigger weight increment than girls at 2 years, amounting to just over 1 lb. both for those premature and mature at birth. In the twin groups the boys again show a bigger weight increment of $\frac{1}{2}$ lb. for those $5\frac{1}{2}$ lb. or less at birth, and $1\frac{1}{2}$ lb. for those above that birth weight. There is very little difference between the sexes in height increment either for single or multiple births.

These results are similar to those given by Lowe and Gibson (1953) who found that mean weight was closely related to birth weight, but that there was

TABLE 1

MALE SINGLETONS. MEAN WEIGHTS AND WEIGHT INCREMENTS FOR DIFFERENT BIRTH WEIGHT GROUPS

Age (mth.)	Birth Weight (lb. oz.)	Weight (oz.)	S.D.	Weight Increment (oz.)	S.D.	No.
6	4.8 and under	219	4.1	159	3.7	46
	4.9 to 5.8	250	4.1	169	3.9	60
	5.9 to 7.8	281	6.8	171	6.8	28
	7.9 and over	297	4.5	160	3.9	30
12	4.8 and under	308	6.4	251	6.1	53
	4.9 to 5.8	336	4.5	254	4.5	62
	5.9 to 7.8	366	8.3	255	8.6	26
	7.9 and over	383	6.7	246	6.6	30
18	4.8 and under	353	6.5	297	6.0	51
	4.9 to 5.8	374	4.4	292	4.3	64
	5.9 to 7.8	413	9.3	302	9.6	26
	7.9 and over	428	8.4	291	8.0	29
24	4.8 and under	394	6.6	335	6.5	53
	4.9 to 5.8	408	4.8	327	5.1	62
	5.9 to 7.8	439	8.5	328	8.3	26
	7.9 and over	457	8.9	321	8.7	30

TABLE 3

MALE TWINS. MEAN WEIGHTS AND WEIGHT INCREMENTS FOR DIFFERENT BIRTH WEIGHT GROUPS

Age (mth.)	Birth Weight (lb. oz.)	Weight (oz.)	S.D.	Weight Increment (oz.)	S.D.	No.
6	4.8 and under	222	6.5	158	5.8	28
	4.9 to 5.8	241	5.3	158	5.3	31
	5.9 to 7.8	272	4.6	171	4.8	42
	7.9 and over	298	4.8	174	6.2	5
12	4.8 and under	296	7.2	235	7.9	25
	4.9 to 5.8	327	9.0	248	9.6	28
	5.9 to 7.8	362	5.8	257	5.7	39
	7.9 and over	365	8.9	240	9.4	6
18	4.8 and under	353	7.6	285	7.8	27
	4.9 to 5.8	378	7.5	294	7.3	29
	5.9 to 7.8	402	6.9	300	6.8	37
	7.9 and over	409	12.2	285	13.0	6
24	4.8 and under	376	8.4	312	8.5	27
	4.9 to 5.8	410	7.1	327	7.2	28
	5.9 to 7.8	442	7.4	343	7.8	39
	7.9 and over	450	17.8	325	18.8	5

TABLE 5

MEAN HEIGHTS AND HEIGHT INCREMENTS AT TWO YEARS FOR DIFFERENT BIRTH WEIGHT GROUPS

	Birth Weight (lb. oz.)	Height (cm.)	S.D.	Height Increment (cm.)	S.D.	No.
Male Singletons	4.8 and under	81.1	1.7	38.9	.9	52
	4.9 to 5.8	84.0	.37	37.9	.47	63
	5.9 to 7.8	86.8	1.47	36.5	.91	26
	7.9 and over	87.4	.58	35.4	.63	29
Male Twins	4.8 and under	82.3	.85	38.6	.71	24
	4.9 to 5.8	83.8	.61	37.0	.77	28
	5.9 to 7.8	86.3	.53	36.9	.63	38
	7.9 and over	84.8	.80	33.4	1.07	5
Female Singletons	4.8 and under	82.7	.65	39.5	.64	42
	4.9 to 5.8	83.2	.43	36.8	.45	74
	5.9 to 7.8	85.2	.53	38.0	.72	37
	7.9 and over	86.4	.68	34.9	.66	19
Female Twins	4.8 and under	80.7	.65	38.1	.67	28
	4.9 to 5.8	82.3	.71	36.3	.79	28
	5.9 to 7.8	84.4	.63	34.9	.77	32
	7.9 and over	87.5	.37	36.9	.94	5

TABLE 2

FEMALE SINGLETONS. MEAN WEIGHTS AND WEIGHT INCREMENTS FOR DIFFERENT BIRTH WEIGHT GROUPS

Age (mth.)	Birth Weight (lb. oz.)	Weight (oz.)	S.D.	Weight Increment (oz.)	S.D.	No.
6	4.8 and under	216	7.3	155	4.1	47
	4.9 to 5.8	227	3.9	152	6.9	75
	5.9 to 7.8	260	8.7	152	3.8	40
	7.9 and over	271	6.1	139	6.5	20
12	4.8 and under	307	6.7	248	3.6	41
	4.9 to 5.8	320	6.5	243	4.8	77
	5.9 to 7.8	339	6.5	231	6.1	39
	7.9 and over	367	9.9	239	11.5	20
18	4.8 and under	352	6.3	294	6.0	43
	4.9 to 5.8	359	5.1	277	5.0	75
	5.9 to 7.8	380	6.2	266	5.3	37
	7.9 and over	407	9.7	271	8.4	19
24	4.8 and under	390	6.8	324	11.0	42
	4.9 to 5.8	395	5.9	314	5.5	75
	5.9 to 7.8	414	5.5	306	6.4	38
	7.9 and over	440	10.4	309	9.9	19

TABLE 4

FEMALE TWINS. MEAN WEIGHTS AND WEIGHT INCREMENTS FOR DIFFERENT BIRTH WEIGHT GROUPS

Age (mth.)	Birth Weight (lb. oz.)	Weight (oz.)	S.D.	Weight Increment (oz.)	S.D.	No.
6	4.8 and under	204	5.8	144	4.6	30
	4.9 to 5.8	239	5.1	157	5.1	34
	5.9 to 7.8	263	6.6	158	6.4	34
	7.9 and over	283	12.8	152	10.5	4
12	4.8 and under	290	7.5	230	7.4	30
	4.9 to 5.8	320	12.9	242	7.6	32
	5.9 to 7.8	342	6.4	241	6.5	36
	7.9 and over	379	11.2	250	9.2	5
18	4.8 and under	338	9.8	277	9.0	29
	4.9 to 5.8	367	7.5	288	7.4	32
	5.9 to 7.8	387	6.4	284	6.0	34
	7.9 and over	427	18.7	322	29.0	4
24	4.8 and under	373	8.0	310	7.7	30
	4.9 to 5.8	390	10.1	310	10.1	28
	5.9 to 7.8	415	5.9	313	5.7	33
	7.9 and over	466	6.6	340	5.7	5

little correlation between weight increment and birth weight. At 3 years the average male increment was 1 lb. greater than that for females. Similarly Falkner (1958) found that the mean weight increment from birth to 2 years was 1½ lb. greater for boys, but there was no difference in mean recumbent length increment for boys and girls between 4 weeks and 2 years of age. He also states that birth weight and early length differences are maintained up to the age of 3 years.

The Effect on Height and Weight of Certain Environmental Factors

It is known that prematurely born children tend to come from an inferior socio-economic background, which may account in part for their failure to catch up in weight and height with those mature

at birth. Information was collected about the environmental background of each case, including the standard of maternal efficiency, frequency of illness and adequacy of the diet.

Maternal efficiency has been graded as: (1) Very good, (2) Good, (3) Fair and (4) Poor. Diet has been graded as: (1) Good, (2) Fair and (3) Poor. Frequency of illness has been graded according to the number of medical conditions requiring attention from the family doctor or hospital admission as follows: (1) No illness. (2) A few minor disorders, e.g., head colds, mild digestive disturbances or mild attacks of specific fevers. (3) One to three more serious infections, e.g., bronchitis, tonsillitis, otitis media or one hospital admission. (4) Four or more infections as above and one hospital admission. (5) Four or more infections and two hospital admissions. (6) Four or more infections and three or four hospital admissions. (7) Four or more infections and five or more hospital admissions. Hospital admissions for surgical conditions such as hernia or pyloric stenosis have not been included.

Table 6 gives mean weight and height increments

at 2 years, for three birth weight groups, by four grades of maternal efficiency. Weight and height increments are substantially higher when maternal efficiency is very good, the effect of maternal efficiency being most marked in those who were premature at birth. Table 7 gives similar means by frequency of medical illness, here graded as: A, no serious illness (1 and 2), B, some illness (3), and C, frequent illness (4, 5, 6 and 7). Again the prematurely born with little or no illness show a marked increase in weight and height increments especially in those smallest at birth. Analyses of weight and height increment by grade of diet are given in Table 8 and show a similar result. Tables 9, 10 and 11 give the proportion of children in the three birth weight groups, by the different efficiency, illness and diet grades.

In the premature groups there is a striking excess of inefficient mothers, frequent illness and poor diet, especially in those who were $4\frac{1}{2}$ lb. or less at birth. To get some idea of the extent to which prematurely born children might catch up in weight and height if they were reared in the most favourable environ-

TABLE 6
MEAN WEIGHT AND HEIGHT INCREMENTS AT TWO YEARS BY EFFICIENCY GRADE OF MOTHER

Birthweight (lb. oz.)	Male			Female		
	4·8 and under	4·9 to 5·8	5·9 and over	4·8 and under	4·9 to 5·8	5·9 and over
Efficiency						
1	347·4	339·0	326·2	328·2	342·2	316·4
2	316·7	311·4	345·1	312·3	311·5	300·0
3	329·3	326·4	346·4	306·1	300·1	304·8
4	295·0	320·7	321·5	281·7	266·8	287·6
Difference between 1 and 4	52·4	18·3	4·7	46·5	75·4	28·8
Height						
1	39·1	39·3	36·4	39·9	37·2	36·1
2	39·1	36·9	36·4	38·1	36·5	35·4
3	39·3	35·8	36·0	38·8	36·8	33·4
4	33·8	34·6	33·0	36·1	31·7	34·1
Difference between 1 and 4	5·3	4·7	3·4	3·8	5·5	2·0

TABLE 7
MEAN WEIGHT AND HEIGHT INCREMENTS AT TWO YEARS BY FREQUENCY OF ILLNESS

Birthweight (lb. oz.)	Male			Female		
	4·8 and under	4·9 to 5·8	5·9 and over	4·8 and under	4·9 to 5·8	5·9 and over
Illness						
A	352·7	334·9	333·5	327·7	327·7	315·3
B	315·1	322·2	328·8	311·0	310·5	308·1
C	309·8	318·8	332·7	290·9	284·9	302·9
Difference between A and C	42·9	16·1	0·8	64·1	42·8	12·4
Height						
A	40·9	38·7	37·1	40·1	37·6	35·3
B	39·7	37·7	35·1	41·6	35·8	36·4
C	37·6	34·9	35·8	36·7	35·4	34·4
Difference between A and C	3·3	3·8	1·3	3·4	2·2	0·9

TABLE 8
MEAN WEIGHT AND HEIGHT INCREMENTS AT TWO YEARS BY GRADE OF DIET

Birth Weight (lb. oz.)	Male			Female		
	4·8 and under	4·9 to 5·8	5·9 and over	4·8 and under	4·9 to 5·8	5·9 and over
Diet			Weight Increment (oz.)			
1	337	330	331	334	326	316
2	322	321	328	295	305	275
3	310	315	347	285	268	287
Difference between 1 and 3	27	15	-16	49	58	29
Diet			Height Increment (cm.)			
1	39·5	38·6	36·4	39·6	37·2	36·2
2	41·0	36·7	35·5	38·1	36·5	33·3
3	37·1	35·1	34·1	37·8	34·8	34·3
Difference between 1 and 3	2·4	3·5	2·3	1·8	2·4	1·9

TABLE 9
EFFICIENCY OF MOTHER BY BIRTH WEIGHT OF BABY

Birth Weight (lb. oz.)	Male			Female		
	4·8 and under	4·9 to 5·8	5·9 and over	4·8 and under	4·9 to 5·8	5·9 and over
Efficiency						
1	38·5	46·8	65·0	55·6	53·4	65·3
2	32·5	29·9	19·0	23·6	27·2	13·7
3	15·0	15·6	10·0	11·1	14·6	15·8
4	13·8	7·8	6·0	9·7	4·9	5·3
Total	100·0	100·0	100·0	100·0	100·0	100·0

TABLE 10
FREQUENCY OF ILLNESS BY BIRTH WEIGHT OF BABY

Birth Weight (lb. oz.)	Male			Female		
	4·8 and under	4·9 to 5·8	5·9 and over	4·8 and under	4·9 to 5·8	5·9 and over
Illness						
A	39·7	37·0	48·5	45·6	54·0	51·6
B	26·9	35·9	35·4	30·9	26·0	28·4
C	33·3	27·2	16·2	23·5	20·0	20·0
Total	100·0	100·0	100·0	100·0	100·0	100·0

TABLE 11
GRADE OF DIET BY BIRTH WEIGHT OF BABY

Birth Weight (lb. oz.)	Male			Female		
	4·8 and under	4·9 to 5·8	5·9 and over	4·8 and under	4·9 to 5·8	5·9 and over
Diet						
1	52·5	56·7	76·0	62·5	59·2	71·1
2	27·5	33·3	20·0	22·2	33·0	22·7
3	20·0	10·0	4·0	15·3	7·8	6·2
Total	100·0	100·0	100·0	100·0	100·0	100·0

mental conditions, a selected group has been extracted from the total premature sample, consisting of those who had a minimum of illness, a good diet and very good maternal care. No difference was found in mean weights when these selected prematures were further divided by social class of father, although as would be expected there was a predominance of children with fathers in social classes 1

and 2.

Fig. 1 shows the mean weights, from birth to 2 years, of selected premature infants who were 4½ lb. or less at birth, those who were between 4½ and 5½ lb. at birth, and the total control group of maturely born infants. By the age of 2 years the smallest singleton premature infants, both male and female, are only 14 oz. below the mean weight of

FIG. 1.—Mean weights of selected prematurely born children and mature controls. 1. Mature controls. 2. Premature: birth weight 4 lb. 9 oz. to 5 lb. 8 oz. 3. Premature: birth weight 4 lb. 8 oz. or less.

the mature controls, the differences at birth being 65 oz. for males and 55 oz. for females. However,

in twin births those who were smallest at birth, even when given the best environmental conditions, are

still substantially behind the control group who were over 5½ lb. at birth, although those with a birth weight between 4½ and 5½ lb. have caught up with the control group.

In height, the selected prematurely born are very little behind the control group at 2 years except for twins who were less than 4½ lb. at birth, who show little reduction in their initial height handicap.

No significant correlation was found between length of gestation and 2-year weight increment. It might be expected that small babies born at term, often to mothers of small stature, would show a smaller weight gain after birth, but this was not obvious at 2 years. Douglas and Mogford (1953) also found no relationship between weight gain and gestation time.

In addition to the social factors already considered, one would expect growth to be influenced by genetic factors. In each case the height of the parents was recorded and those data included in the subsequent analysis.

Correlation and Regression Analysis

Tables 12 and 13 give the first order correlation coefficients between weight and height increments at 2 years and the following factors: mother's

height, father's height, frequency of illness, the seven grades of illness frequency being used in this analysis, diet, maternal efficiency and social class of father. Two factors (mother's height and father's height) are presumably mainly genetic, and four (illness, diet, maternal efficiency and social class) are primarily environmental. The separation is not absolute. Heights of the parents will depend to some extent on diets in their own youth, and so will be partly socially conditioned. It was shown in a previous study, including these same women (Drillien, 1957), that mothers of premature babies are, on the whole, significantly shorter than mothers of mature controls and that average height was related to the woman's environment during childhood. The correlations will be reduced by imperfections in the assessment or measurement of the factor concerned. This is likely to affect in particular the social factors of diet and maternal efficiency which could only be approximately specified. The heights of mothers were recorded accurately during their stay in hospital, but a record of father's height was obtained by enquiry and is therefore less reliable. The correlation coefficients found may therefore be regarded as minimal and the true values, if they could be observed, would in general

TABLE 12
FIRST ORDER CORRELATION COEFFICIENTS BETWEEN WEIGHT INCREMENT AT TWO YEARS AND VARIOUS FACTORS

	Premature Singleton		Twins		Mature Singleton	
	Male	Female	Male	Female	Male	Female
No. of Cases	111	103	99	92	55	49
Weight Increment and:						
Mother's height	·1837	·4416	·2801	·3840	— ·0162	·2966
Father's height	·2456	·3692	·2732	·3769	·3138	·2055
Illness	— ·2368	— ·3114	— ·2830	— ·3654	— ·1446	— ·2325
Diet	— ·1482	— ·3952	— ·1974	— ·3072	— ·0771	— ·2233
Mother's efficiency	— ·1526	— ·2905	— ·2755	— ·2942	— ·0790	— ·1725
Father's social class	— ·2011	— ·2279	— ·1234	— ·2255	— ·1601	— ·2708
Baby's birth weight	— ·1089	— ·1064	— ·1408	— ·1572	— ·0092	— ·1238
Minimum value for significance at 5% point	·1867	·1939	·1978	·2053	·2656	·2815

TABLE 13
FIRST ORDER CORRELATION COEFFICIENTS BETWEEN LENGTH INCREMENT AT TWO YEARS AND VARIOUS FACTORS

	Premature Singleton		Twins		Mature Singleton	
	Male	Female	Male	Female	Male	Female
No. of Cases	109	102	98	90	54	48
Length Increment and:						
Mother's height	·2890	·3777	·3082	·1702	·5020	·4504
Father's height	·3045	·3423	·1567	·2350	·3106	·3229
Illness	— ·2345	— ·1549	— ·2215	— ·2272	— ·3439	— ·0592
Diet	— ·1414	— ·2336	— ·2132	— ·0708	— ·0533	— ·3196
Mother's efficiency	— ·2354	— ·1941	— ·2999	— ·2097	— ·1764	— ·1959
Father's social class	— ·2045	— ·1361	— ·1621	— ·2404	— ·2537	— ·1233
Baby's birth weight	— ·2616	— ·2816	— ·3335	— ·1890	— ·1983	— ·1118
Minimum value for significance at 5% point	·1884	·1949	·1988	·2706	·2680	·2845

be higher. Tables 12 and 13 indicate that the correlations between weight and length increments, and the genetic factors are comparable in magnitude to those with the social factors. In the premature and twin groups there is good concordance, the differences observed being within the expected range of random fluctuation. Not all the individual coefficients are statistically significant, but joint tests combining the four groups of male and female prematures and twins, show that the overall significance is beyond question for each of the separate genetic and social factors. As noted previously, the prematurely born singletons show a negative correlation between birth weight and weight increment, whilst the twins show a positive correlation indicating that there is a tendency for the singleton prematures to reduce their initial weight handicap by 2 years, though in the case of twins the reverse applies. However, in no case is the correlation coefficient significant at the 5% point. When height increment is considered, a negative correlation between length at birth and height at 2 years is found for all groups of singletons and twins, and taken together these findings are statistically significant. In the mature groups numbers are smaller and the significance of results thereby lowered.

In general, social factors appear to be relatively less important and genetic factors more so in those mature at birth. Of the social factors studied, frequency of illness gives the highest and most consistent correlations in the premature and twin groups. This is no doubt due to the fact that greater accuracy was possible in recording these data than

for the other social factors, except for social class which *per se* seems of least importance in determining rate of growth. The various social and genetic criteria are not independent of one another. To disentangle the relative contributions of the different factors, extensive use has been made of the techniques of multiple correlation and regression analysis. For this it was necessary first to find the correlation of each of the factors employed with all the others. Table 14 gives these correlations and levels of significance.

Mother's height is quite highly correlated with father's height in each group, indicating a fairly high degree of assortative mating. Parental heights are also correlated significantly with all the social factors excepting frequency of illness. Frequency of illness is correlated with diet, social class and maternal efficiency, the last correlation, about .5, being very high. Diet is correlated highly with social class and very highly with maternal efficiency, the values being about .45 and .75. Many multiple regressions were computed relating weight and length increment to various combinations of the genetic and social factors listed in Tables 12 and 13. In general, a combination consisting of mother's height (M), father's height (F) and one or two of the social factors will give significant, or near significant, regression coefficients for all factors included, but the most significant social factor varies in the different groups of infants. This is not surprising, for, as Table 14 shows, all social factors are quite highly intercorrelated among themselves. Each one is a more or less adequate partial measure of the others. The social factor which most often gave

TABLE 14
CORRELATION COEFFICIENTS BETWEEN THE VARIOUS GENETIC AND SOCIAL FACTORS EMPLOYED IN THE ANALYSIS

	Premature Singletons		Twins		Mature Singletons	
	Male	Female	Male	Female	Male	Female
No. of Cases	111	103	99	92	55	49
Mother's Height and:						
Father's height	.2581	.5093	.4392	.3809	.2321	.4958
Illness	-.0404	-.1390	-.1303	-.1930	-.0384	-.0633
Diet	-.2070	-.2236	-.2713	-.3595	-.0554	-.2399
Mother's efficiency	-.1718	-.2888	-.2991	-.3175	-.2510	-.2048
Father's social class	-.2079	-.2232	-.1760	-.2740	-.2218	-.1107
Father's Height and:						
Illness	-.0350	-.0857	-.1783	-.2693	-.0402	-.3512
Diet	-.2008	-.2036	-.4063	-.3670	-.1472	-.2260
Mother's efficiency	-.1610	-.1968	-.3466	-.4195	-.1122	-.2983
Father's social class	-.1867	-.2006	-.3504	-.2447	-.1337	-.2722
Illness and:						
Diet	.2405	.4263	.3894	.4656	.4500	.5404
Mother's efficiency	.5335	.4962	.5204	.4414	.4483	.4962
Father's social class	.2657	.2837	.3136	.1251	.3305	.5275
Diet and:						
Mother's efficiency	.7676	.7210	.7805	.8362	.7464	.7201
Father's social class	.5291	.3745	.4603	.4673	.3965	.4188
Mother's efficiency and:						
Father's social class	.5369	.4142	.5275	.5342	.4432	.5344
Minimum value for significance at 5% point	.1867	.1939	.1978	.2053	.2656	.2815

the highest regression coefficient, in combination with parental heights, was frequency of illness (I). The regression coefficient for the combination of three factors, M, F and I, is shown in Table 15. Column 1 shows the regression coefficients when all variates are scaled so that the standard deviations are unity. These are strictly comparable with the correlation coefficients set out in Tables 12 and 13, and indicate what the correlation between weight or length increment and the particular factor would be if the other factors were held constant. Column 2 gives the F tests of significance for these coefficients. A figure of 4 or more indicates significance at the 5% level. Column 3 gives regression coefficients in terms of the actual measurement. These figures give the average excess weight increment in ounces, or height increment in centimetres, per inch extra height in mother or father, and per unit decrease in the grading scale for illness. In weight one would expect an increased increment of about 4 oz. for every extra inch in mother's height, 3 oz. for each extra inch in father's height and $\frac{1}{2}$ lb. decrease in weight increment for each increase in illness frequency grading from one to seven.

The standard deviation for maternal height is about 2.4 inches and for paternal height about 2.9 inches, the range of mother's height being 10 inches, and 12 inches for fathers (i.e., 95% of the heights are included in the range mean height ± 2 S.D.). Therefore one would expect a difference in weight increment at 2 years of about 40 oz. between children of the shortest and tallest mothers, rather less between the children of the shortest and tallest fathers, and $3\frac{1}{2}$ lb. between those in the lowest and highest illness frequency grades. Similarly in height, one would expect an increased

increment of about .7 cm. for every extra inch in mother's height, .4 cm. for every extra inch in father's height, and 1 cm. decrease in height increment for each increase in illness grade.

In spite of the inevitable fortuitous variation between the comparable coefficients there is a consistent picture. Whether for weight or height increment the primarily genetic factors (M and F) and the representative environmental factor (I) have a significant influence when the other type of factor has been fully taken into account. Perhaps the best way of expressing this is to work out the partial multiple correlation coefficients as shown in Table 16. These give the multiple correlations between weight or length increment and (1) Mothers' and fathers' heights, when all social factors are held constant. (2) Social factors (illness, diet and maternal efficiency), when parental heights are held constant.

It is evident that these partial coefficients are comparable in magnitude, with the genetic coefficients on the whole rather higher. Considering that parental heights themselves contain a social component and that the correlations with social factors are more likely to be attenuated by unavoid-

TABLE 16
PARTIAL MULTIPLE CORRELATION COEFFICIENTS

	Singleton Premature		Twins	
	Male	Female	Male	Female
Weight Increment and: Parental heights* Social factors†	.2601 .2484	.4359 .3846	.2683 .2584	.3665 .2811
Length Increment and: Parental heights* Social factors†	.3697 .2581	.3792 .1602	.2500 .2530	.1896 .2990

* Parental heights held constant † Social factors held constant.

TABLE 15
COEFFICIENTS FOR MULTIPLE REGRESSION OF WEIGHT OR LENGTH INCREMENT ON PARENTAL HEIGHT AND FREQUENCY OF ILLNESS

	1 Regression Coefficients in Standard Measure (partial Correlations)			2 F Values for Regression Coefficients			3 Regression Coefficients in Units of Measurement (Increment per inch height) (Increment per illness grade)		
	M	F	I	M	F	I	M	F	I
Premature Singletons:				Weight Increment at 2 Years (oz.)					
Males	.1214	.2065	-.2247	1.682	4.868	6.166	2.2333	3.1556	- 8.6743
Females	.3099	.1898	-.2520	9.731	3.695	8.626	5.4279	2.9282	-11.7322
Twins:									
Males	.1834	.1513	-.2321	3.053	2.047	5.866	3.1632	2.5719	- 8.7757
Females	.2538	.2102	-.2598	6.584	4.352	7.487	4.0116	2.8555	- 8.6260
Premature Singletons:				Length Increment at 2 Years (cm.)					
Males	.2271	.2452	-.2253	6.330	7.379	6.604	.7055	.6272	- 1.4576
Females	.2608	.2004	-.0994	5.942	3.558	1.159	.8629	.5806	- .8702
Twins:									
Males	.2868	-.0013	-.1885	7.179	.0002	3.718	.9597	-.0043	-1.3884
Females	.0764	.1581	-.1637	.469	1.916	2.269	.2394	.4264	-1.0809

able inaccuracy of the assessments, it may be fairly concluded that in the groups studied genetic and environmental factors are of approximately equal importance in their influence on growth, whether measured by weight or by length increment during the first 2 years.

In few studies of the growth of prematurely born children has attention been paid to social background. Hess, Mohr and Bartelme (1934), using a control group of siblings, found that prematurely born boys had caught up in weight and height by 3 years, and girls somewhat earlier, except for those who were less than 3½ lb. at birth. They point out that these children were all specially supervised from birth unlike the control group. Thirty per cent of their premature sample were first born and had no controls. Douglas and Mogford (1953) found that their premature group were lighter and shorter than their controls at 4 years. The mothers of those prematures who caught up or surpassed the controls by 4 years were taller and heavier than the mothers of those who failed to catch up. They conclude that the height of the mother gives the best indication of the likely growth pattern of her premature baby and that the small size of certain prematurely born children is genetically determined.

Summary

A statistical analysis is presented of a study of physical growth, in the first 2 years of life, in a group of 600 premature and maturely born children, including 200 twin births. The following conclusions were reached:

Throughout the 2-year period mean weights are closely related to mean birth weight. The smallest prematurely born singletons show a small increase in weight increment at 2 years. The smallest twins show a smaller weight increment, but neither finding is statistically significant.

In height, those largest at birth maintain their height superiority at 2 years, but there is a significant excess height increment in those smallest at birth.

Boys show a greater weight increment at 2 years than girls. There is little difference between the sexes in height increment.

Rate of growth whether measured by weight or height increment is affected by certain environmental factors. Substantially higher increments are recorded when maternal efficiency and diet are considered to be good, and frequency of illness is minimal. Environmental factors appear to exert a more marked influence on growth in the prematurely born than in the mature controls. In all premature groups there is a striking excess of inefficient mothers, poor diet and frequent illness.

Prematurely born singletons reared in the most favourable environmental conditions have very nearly caught up with the mature group in both weight and height by 2 years. This applies also to twins who were over 4½ lb. at birth, the smaller twins still being substantially behind the control group.

Genetic factors as deduced from parental heights also have an influence on rate of growth. Genetic and environmental factors were intercorrelated to quite a high degree. Using the technique of correlation and regression analysis it was found that genetic and environmental factors are of approximately equal importance in their influence on growth whether measured by weight or height increment at 2 years.

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