DISSOCIATION IN THE PONDERAL AND STATURAL GROWTH OF THE ATROPHIC INFANT.

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Malnutrition in infancy and childhood is without doubt a most important problem not only from the practical but also from the scientific point of view. Hence there is little wonder that it has been the subject of much research both in the ward and in the laboratory. During the last three decades particularly, many investigations have been carried out, and while there is no question that these have contributed to a better understanding of the problem, certain points of importance have either been insufficiently explored or insufficiently explained. One of these questions is the growth in length of the atrophic infant.

Growth is one of the chief activities of the infantile organism and involves both increase in bulk and increase in length. Although both the increase in amount of the soft tissues and of the skeleton steadily progress, there is no constant relationship between them. They are to a certain extent independent of one another as is shown from the percentage increase and rate of increase during the first two years of life. In the normal male infant, for instance, the percentage increase in weight is much greater than in that of the length, but the rate of fall in the increase is slower in the case of the length than in that of the weight (See Table 1).

TABLE No. 1.

Showing the percentage increase in weight and length in six-monthly periods in males during the first two years of life.

Period	Weight		Length	
	Absolute increase	Percentage increase	Absolute increase	Percentage increase
0 to 6 mths.	3.83 kils.	111.0	12.3 cms.	23.4
6 to 12 "	1.98 "	27.2	9.0 "	13.9
12 to 18 "	1.21 "	13.0	2.5 "	3.3
18 to 24 "	1.67 "	15.0	6.5 "	8.5

If this want of parallelism between weight and height is evident during health, it would seem possible that in disease, as, e.g., malnutrition, it might become more apparent. It was to study this very question that the present investigation was undertaken and especially to establish, in so far as it is possible, at what stage of the atrophy retardation in the rate of growth in length sets in.

Previous Work.

The relationship between height and weight in health and disease has of course been investigated by previous workers. Variot,⁽¹⁾ for example, in 1908 drew attention to the absence of association which exists between growth in weight and growth in height in the normal infant, and he stated that this was even more

marked in the case of the atrophic or malnourished infant. Variot noted that during the course of malnutrition growth in weight was first affected and then later that in length, and he expressed the opinion that length was a better index of the physical development of the infant than weight. As he succinctly expressed it, "Infants are as old as their length and not their weight."

Fleischner,⁽²⁾ as the result of his investigations of the relation which exists between the weight and length in the normal and undernourished infant, established that if the gain in weight slowed down the gain in the length did the same, but to a smaller extent. According to him growth in height depends upon the slight influence which age exerts upon the development of the body independently of the weight.

Putnam⁽³⁾ also studied this question and came to the conclusion that children, even when they are extremely undernourished, have a fairly normal development of their skeleton for their age.

Meyer⁽⁴⁾ also maintains that retardation of the gain in weight and height is not always parallel. Thus an infant of three months, if atrophic, can have its normal height even although its weight has scarcely moved forward since its birth. But according to Meyer matters are quite different in infants between 6 and 12 months of age. At this age any marked stagnation of the gain in weight may be accompanied by a retardation of the growth in length. However, as soon as the cause is removed, growth in length will recommence and in due time the loss of height is made up, but this process is slow and in no circumstances will it be fully compensated for before the end of the first year.

Similarly other workers, e.g., Czerny and Keller,⁽⁵⁾ believe that in the case of the under-nourished infant the weight alone suffers at first and that for a certain length of time height remains unaffected. According to these authors starvation over a prolonged period is necessary to cause any retardation of the growth in length, and, like Variot, they believe that the length is a more reliable measure of the degree of atrophy in the infant than is the state of its nutrition.

Marfan⁽⁶⁾ and some other workers of the French School divide malnutrition of the infant into three stages, basing their classification upon the extent to which there is loss of the subcutaneous fatty tissue. 1. The first stage of atrophy is the state which corresponds to the loss of the fat reserves over the abdomen, thorax and lumbar regions. In this degree of atrophy the actual weight lags behind the expected weight, but the growth in length continues to be normal. 2. The second stage of atrophy embraces those cases in which all the fatty reserves except those in the face have disappeared. If this state neither improves nor grows worse, i.e., remains stationary, the state which Variot terms "hypotrophie infantile" ensues. This state generally ends in recovery, but the infants have a subnormal weight and height for the next year or two. However, the retardation in the development does not leave behind any unfavourable traces later on in life (Mouriquand⁽⁷⁾). 3. The third stage of atrophy, or Parrot's athrepsie which corresponds to Finkelstein's "dekomposition," is the state in which all the fat reserves, even those of the face, have disappeared and in which growth in length has definitely stopped.

Finally, mention may be made of the opinion of Lesné and Binet⁽⁸⁾ that there is absolutely no relationship between the growth in height and gain in weight in the infant.

These several references to current opinion reveal the conflicting views held by different workers on this fundamental question. While most authors note the dissociation between growth in height and growth in weight in health and admit that in disease this may be even more marked, there is no unanimity regarding the conditions under which it occurs nor is there any evidence of a definite attempt having been made to discover the particular factor, or group of factors, which are to blame. It was to help in the elucidation of this very problem that the present investigation was undertaken.

Material Studied.

The present study is based upon the investigation of 135 infants showing different degrees of nutrition. Most of them were in the first year of life and were selected from a total of 1,500 infants who have attended this Institution during the past eight years.

All the infants selected for the study were full-time babies and at birth had a normal weight and height. Special care was taken to eliminate those with ailments which might be due to disease of the endocrine glands, as well as those suffering from some chronic infection. Care has also been taken to exclude all cases suffering from acute disorders of the digestive system, as well as those in which there was found at the time of weighing a sudden loss of weight. The study is therefore entirely based upon cases which were suffering from the chronic disturbances of digestion and nutrition.

As standards of height and weight we have adopted Pirquet's values which are usually employed in this country. In this connection it must be borne in mind, however, that this author gives the same values for height in both males and females, whereas his values for weight are slightly lower for female than for male infants. Although the sex of the infants is not indicated in the various tables of our own findings, this factor has been taken into account by calculating the percentage of the weight on the basis of the mean value between the values given for the male and those for the female infants. This has been done all the readier because Pirquet's values are nothing else but the average.

In measuring the length it has always been done with the infants in the recumbent posture, the child being laid in a special trough in which he could be satisfactorily placed and stretched out so that even the slightest error in the measuring could be eliminated.

Results.

The infants which are the subject of this study can be divided into three main groups. The first group comprises twenty infants whose actual weight is at most one third lower than the normally accepted weight for their age. The second group consists of the infants at different stages of malnutrition whose actual weight is less than two thirds of their expected weight (21 of these infants are three months old, 47 six months old, 39 nine months of age, 18 are twelve months and 8 are in their second year of life). Finally, the third group comprises 24 infants who are in varying nutritional states and of different ages but who have been under prolonged observation.

In the various tables of findings the cases are arranged in the order which corresponds to the degree of their nutritional condition. This method was adopted not only for the sake of a better review of the material but also to enable one to gauge, with less difficulty, any relation which exists between the state of nutrition and the height, as well as the influence which the factor of duration of the nutritional abnormality exerts on the growth in height of the atrophic infant.

Group I.

TABLE No. 2.

Showing the relation between the state of nutrition and the retardation in the growth of height in twenty infants of different ages. The nutritional condition of these infants, as expressed in the percentage of expected weight, corresponds at least to two thirds of the actual weight for their age.

Case No.	Age months	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Growth in length in cms. above +, equal to 0, or less than - the standard
1	3	5.230	87	61	+1
2	3	4.990	84	60	0
3	3	4.920	81	60	0
4	3	4.300	72	59	-1
5	6	6.730	88	65	-1
6	6	6.320	82	65	-1
7	6	5.780	74	64	-2
8	6	5.300	69	65	-1
9	6	5.220	68	64	-2
10	9	7.740	86	71	0
11	9	7.110	80	70	-1
12	9	6.480	73	69	-2
13	12	8.730	87	73	-2
14	12	8.320	83	75	0
15	12	7.880	79	74	-1
16	12	6.700	67	73	-2
17	15	8.790	84	76	-1
18	15	8.080	78	76	-1
19	18	9.110	81	79	-1
20	18	8.400	75	78	-2

From the above findings it would appear that in infants, irrespective of age, who are only one third lighter than what they should be for their age, there does not exist any marked deviation from the physiological dissociation between the growth in weight and height. Any retardation in the growth of height that is present is very slight, and is more probably evidence of individual and inherited tendencies than of any association with malnutrition. On the average the deviation from Pirquet's values in these infants amounted to 1.3 c.m.

Group II.

TABLE No. 3.

Showing the relation between the state of nutrition and the retardation in the growth of height in 21 infants three months of age.

Case No.	Actual body weight kgr.	Percentage of expected weight.	Actual height cm.	Retardation of the growth in length cm.
1	4.030	66	59	1
2	4.010	66	59	1
3	3.930	65	57	3
4	3.890	65	58	2
5	3.870	65	58	2
6	3.870	65	57	3
7	3.800	63	57	3
8	3.780	63	57	3
9	3.770	63	57	3
10	3.750	63	58	2
11	3.750	63	56	4
12	3.720	62	58	2
13	3.710	62	57	3
14	3.700	62	57	3
15	3.630	60	56	4
16	3.610	60	56	4
17	3.400	57	57	3
18	3.390	57	60	0
19	3.220	53	56	4
20	3.180	53	55	5
21	3.030	50	55	5

Sub-group A. (Table No. 3.):—This group comprises 21 atrophic infants who are three months old and who are in a state of nutrition which corresponds to the percentage between 66 and 50 of the expected weight. Seven of them show a retardation in the growth of height from 0 to 2 cm.; eight of them show a retardation in the growth of height of 3 cm.; and in six of them this amounts to 4 or 5 cm. Thus the retardation in the growth in height is not the same for all: nor is there any apparent connection, except in the last six cases, between the amount of the retardation in height and the state of their nutrition. The only explanation which can be offered for this finding rests on the history of the feeding of those infants. The first seven cases did thrive for a time and only later began to lose weight, whereas the other cases had been starved from birth so that in them there had been the longest period of malnutrition. The average retardation in the growth of height in this group of infants amounts to 2.8 cm.

TABLE No. 4.

Showing the relation between the state of nutrition and the retardation in the growth of height in 47 infants six months of age.

Case No.	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.	Case No.	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
1	5.140	66	63	3	25	4.290	56	60	6
2	5.120	66	61	5	26	4.270	56	63	3
3	5.100	66	63	3	27	4.250	56	58	8
4	5.050	65	62	4	28	4.220	55	58	8
5	4.920	64	59	7	29	4.200	55	58	8
6	4.810	63	62	4	30	4.200	55	58	8
7	4.790	62	61	5	31	4.180	55	62	4
8	4.730	62	60	6	32	4.160	55	61	5
9	4.700	61	63	3	33	4.160	54	62	4
10	4.690	61	60	6	34	4.120	53	60	6
11	4.680	61	61	5	35	4.100	53	60	6
12	4.680	61	61	5	36	4.100	53	58	8
13	4.650	61	62	4	37	4.070	53	58	8
14	4.630	60	63	3	38	4.060	53	60	6
15	4.600	60	62	4	39	3.920	51	59	7
16	4.590	60	61	5	40	3.900	51	60	6
17	4.580	60	62	4	41	3.880	50	60	6
18	4.410	59	59	7	42	3.800	50	60	6
19	4.390	58	59	7	43	3.540	46	58	8
20	4.370	58	63	3	44	3.500	46	60	6
21	4.340	58	58	8	45	3.420	45	56	10
22	4.330	56	62	4	46	3.380	44	56	10
23	4.330	56	60	6	47	3.010	39	58	8
24	4.300	56	62	4					

Sub-group B. (Table No. 4.):—All the infants in this group were aged six months. The state of their nutrition expressed in the percentage of the expected weight varies between 66 and 39. However, not even in this group of cases do we notice any special constancy in the relation between the state of nutrition and the degree of retardation in the growth of length. In so far as any relation does exist it is at least not very marked. The retardation when present is, however, greater in this group than in the previous one, varying between 3 and 10 cm. This state of matters may be accounted for by the length of time during which these infants may have been under-fed. The average retardation in the growth of height for this group of cases amounts to 5.8 cm.

TABLE No. 5.

Showing the relation between the state of nutrition and the retardation in the growth of height in 39 infants nine months of age.

Case No.	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.	Case No.	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
1	5.920	66	66	5	21	5.120	58	65	6
2	5.900	66	64	7	22	5.040	56	65	6
3	5.880	66	65	6	23	5.000	56	64	7
4	5.880	66	63	8	24	4.990	56	65	6
5	5.790	65	64	7	25	4.930	55	59	12
6	5.780	65	63	8	26	4.900	55	63	8
7	5.720	64	64	7	27	4.880	55	65	6
8	5.700	64	63	8	28	4.850	55	65	6
9	5.630	63	68	3	29	4.730	53	63	8
10	5.410	61	65	6	30	4.710	53	60	11
11	5.390	61	62	9	31	4.700	53	64	7
12	5.390	61	65	6	32	4.620	52	61	10
13	5.380	61	64	7	33	4.600	52	62	9
14	5.360	61	66	5	34	4.410	50	62	9
15	5.360	61	66	5	35	4.320	48	58	13
16	5.330	61	65	6	36	4.040	45	61	10
17	5.220	60	64	7	37	3.920	44	60	11
18	5.200	60	62	9	38	3.800	43	59	12
19	5.180	59	63	8	39	3.670	41	57	14
20	5.130	58	63	8					

Sub-group C. (Table No. 5.):—This group contains 39 atrophic infants, aged nine months. They are in a state of nutrition which corresponds to the percentage between 66 and 41 of the expected weight. The relation between the state of nutrition and the retardation in the growth of height in these cases appears to be slightly more constant, and on the whole, it is greatest in those who are most under-weight. The average retardation for this group amounts to 7.8 cm.

TABLE No. 6.

Showing the relation between the state of nutrition and the retardation in the growth of height in 18 infants twelve months of age.

Case No.	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
1	6.580	66	67	8
2	6.520	65	68	7
3	6.290	63	69	6
4	6.110	61	65	10
5	5.900	59	66	9
6	5.820	58	66	9
7	5.370	54	67	8
8	5.370	54	67	8
9	5.360	54	61	14
10	5.330	53	66	9
11	5.300	53	66	9
12	5.290	53	66	9
13	5.270	53	63	12
14	5.120	51	62	13
15	5.030	50	65	10
16	4.930	49	61	14
17	4.430	44	62	13
18	4.210	42	62	13

Sub-group D. (Table No. 6.):—In this group are 18 atrophic infants aged twelve months. Their state of nutrition corresponds to the percentage between 66 and 42 of the expected weight. In this group, as in the previous one, the relation between the state of nutrition and the retardation in the growth in height is fairly constant and shows an increasing correlation with the degree of emaciation. The average retardation in growth in length for this group amounts to 10 cm.

TABLE No. 7.

Showing the relation between the state of nutrition and the retardation in the growth in 8 infants during the second year of life.

Case No.	Age months	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
1	15	6.930	66	69	8
2	15	6.520	62	70	7
3	15	6.090	59	67	10
4	15	5.600	54	70	7
5	18	6.700	59	71	9
6	18	4.480	40	63	17
7	21	7.430	64	72	10
8	24	8.170	66	75	10

Sub-group E. (Table No. 7.):—This group contains 8 infants in the second year of life. Four of them are 15 months, two 18 months, one 21 months and one

24 months old. The state of their nutrition expressed in the percentage of their expected weight varies between 66 and 40. In this group the same relationship between loss of weight and diminution in height is also apparent, and it is present to a more marked extent than is to be observed in any previous group. We would specially direct attention to Case No. 6. This infant was full-time, aged 18 months and weighed only 4,480 grammes, i.e., 40% of the expected weight, and measured in length 63 cm. which is a retardation in growth of the length amounting to 17 cm.

Group III.

This group consists of 24 children in the first and second years of life who had been under our care sufficiently long to enable periodic observations to be made regarding the relative rates of increase in weight and height during the stage of recovery (See Table 8).

TABLE No. 8.

Showing the relation between the state of nutrition and the retardation in the growth of height in 24 infants of different ages who were under observation for a longer period of time.

Case No.	Age months	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
1	12	5.340	53	66	9
	15	7.390	71	72	5
	18	9.320	83	77	3
	21	9.720	84	81	1
2	6	3.490	46	60	6
	9	4.610	52	64	7
	12	5.930	59	66	9
	15	6.560	62	70	7
	18	8.810	79	74	6
3	6	3.530	46	58	8
	9	4.900	55	59	12
	12	7.490	75	65	10
	15	8.720	83	67	10
	18	9.640	86	70	10
	21	11.400	98	76	6
4	6	4.820	63	62	4
	9	5.230	57	65	6
	12	7.470	75	70	3
	15	9.800	94	74	5
5	6	3.890	50	60	6
	9	5.100	58	63	8
	12	6.820	68	67	8
	15	8.700	83	74	3
6	6	4.230	55	58	8
	9	5.220	59	62	9
	12	7.460	74	70	5

Case No.	Age months	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
7	6	5.430	61	65	6
	12	7.040	70	68	7
	15	9.120	87	75	2
8	6	4.390	58	60	6
	9	5.420	61	64	7
	12	7.240	72	68	7
	15	9.510	91	75	2
	18	11.400	101	78	2
9	6	4.200	55	58	8
	9	5.780	65	63	8
	12	7.270	73	68	7
10	6	4.490	58	63	3
	9	5.900	66	65	6
	12	8.470	85	70	5
	15	8.910	86	76	1
	18	10.900	97	81	1
11	6	4.230	55	60	6
	9	5.870	66	64	7
	12	7.860	79	69	6
	15	8.830	84	73	4
12	6	4.530	59	59	7
	9	5.820	65	64	7
	12	6.570	66	68	7
	15	7.630	72	71	6
	18	8.210	73	74	6
	21	9.900	86	77	5
13	6	5.140	67	60	6
	9	6.620	75	66	5
	12	8.160	81	70	5
	15	10.000	96	74	3
	18	11.600	103	78	2

TABLE No. 8.—*Continued.*

Case No.	Age months	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
14	6	5.090	66	63	3
	9	6.730	75	67	4
	12	8.380	84	71	4
15	6	5.230	68	61	5
	9	6.620	75	67	4
	12	8.470	85	72	3
	15	9.510	91	74	3
	18	10.730	96	78	2
	21	11.000	96	80	2
16	6	5.370	69	61	5
	9	6.690	77	68	3
	12	8.370	83	73	2
	15	10.440	100	78	+1
	18	11.720	140	81	+1
17	6	4.290	56	58	8
	9	6.730	75	67	4
	12	7.960	80	70	5
	18	11.320	100	79	1
18	6	5.070	66	61	5
	9	6.420	72	65	6
	12	8.570	86	69	6
	24	11.830	95	81	1
19	6	3.390	44	56	10
	9	4.310	48	58	13
	12	5.320	53	61	14

Case No.	Age months	Actual body weight kgr.	Percentage of expected weight	Actual height cm.	Retardation of the growth in length cm.
20	6	5.120	67	61	5
	9	6.430	72	65	6
	12	7.670	77	71	4
	15	8.940	85	74	3
	18	8.900	79	77	3
	21	9.130	78	80	2
21	24	9.500	76	83	2
	9	5.170	59	63	8
	12	5.760	58	66	9
	15	7.540	71	72	5
22	18	9.030	80	76	4
	6	4.270	55	60	6
	9	3.980	45	61	10
23	12	4.970	50	65	10
	15	6.130	59	67	10
	18	6.700	59	71	9
	21	7.380	64	72	10
	24	8.220	66	75	10
	6	4.870	64	59	7
24	9	5.930	66	63	8
	12	6.880	69	67	8
	3	5.630	94	62	+2
25	6	5.700	74	65	1
	9	5.380	61	66	5
	12	5.410	54	67	8

A scrutiny of the above table reveals the following facts:—

(1) The findings in general support the observations made in the previous groups that all infants over three months of age whose weight is less than two-thirds of that expected for their age show a diminution in length.

(2) All infants having a weight one-third less than the expected weight for their age, and even although the state of nutrition may be improving, show no tendency to grow in length; on the contrary they may show during this period a further retardation.

(3) When the infant has reached 66 or more per cent. of its expected weight there is a tendency for the growth in length to be resumed. Thus just as in the process of emaciation an infant loses first in weight, so when an atrophic infant begins to improve it gains first in weight and then in height.

(4) The making up of the loss in height depends not only on the improvement of nutrition but also on the question of time. Eleven cases had regained

their normal height in periods varying between 6 and 18 months, but in thirteen, even after 18 months, the children were still under-height.

Case No. 22 is a specially striking example in which retardation in the growth in height remains at the same level for 15 months, while the state of nutrition varied between 45% and 66% of the expected weight for age. Case No. 23 behaved in a similar manner.

Case No. 24 also deserves special mention. This was an infant who weighed 94% of its expected weight at the age of three months and only 54% at the age of twelve months. It will be seen that it was only when the weight had fallen to 61% of the expected weight for age that any retardation in growth in length became evident.

Cases Nos. 1, 5, 7, 8, 10, 13, 15, 16, 17, 18 and 20 show that recovery in height may occur but that it lags behind recovery in weight.

General Conclusions.

(1) The atrophic infant, irrespective of age, does not show any evidence of arrest of growth in length until the weight has fallen below $\frac{2}{3}$ of the expected weight for age.

(2) The infant, except during the first three months of life, suffers from arrest of growth in length when the weight has fallen below $\frac{2}{3}$ of the expected weight for age.

(3) The retardation of growth in length bears a definite relationship to the age of the child. In the cases observed the average retardation in height was in children three months old 2.8 cms., in children six months old 5.8 cms., in children nine months old 7.8 cms., and in children one year old 10 cms.

(4) Thus both the degree of atrophy and the age of the child, or in other words the probable duration of malnutrition, are the factors which govern arrest of growth.

(5) So long as a child is less than $\frac{2}{3}$ of its expected weight improvement in the nutritional state is not accompanied by recovery of growth in length.

(6) During recovery of the atrophic infant gain in weight takes place first, just as during the development of the condition loss of weight precedes loss in height.

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