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LATE "CATCH-UP" GROWTH AFTER SEVERE INFANTILE MALNUTRITION[1]

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Prolonged observations of children severely malnourished in early life suggested that permanent stunting in body length and head size resulted (1, 2). Studies with small laboratory animals lent support to these observations (3). Besides the obvious species differences, there were other important distinctions between the two types of studies. Whereas the experimental animals after the early insult received an optimum diet, the children, almost without exception, continued to live in the same environment in which they had become severely malnourished originally. This makes it impossible to distinguish between the late effects of early malnutrition and the effect of life-long existence in the conditions of extreme proverty, where adequate nutrition is most unlikely.

Although one important study indicated that severely malnourished infants failed to catch up to their seemingly healthy siblings (4), others indicated that they very nearly (5) or actually (6) did so. Our own observations indicated that the so-called *healthy* siblings in this type of study were themselves growing well below their genetic potential (5).

In an earlier set of observations we called attention to the wide variability in "catch-up" growth, noting that some children made up most of the apparent deficit while others acquired additional deficits after discharge from the hospital or convalescent unit (2). The group as a whole demonstrated only a modest return toward *normal* over the years. Subsequently we noticed that the most impressive recoveries were made by children who experienced a dramatic change in their environment some time after discharge.

The present report deals with the growth of eight children, out of more than 150 being followed, who were selected on the sole basis of having been transferred to a new environment during rehabilitation. The malnourished infants and children who are

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admitted to our unit at the British American Hospital come from desperately poor families in the peripheral slums of Lima, Peru. They live in one-room shacks without flooring, windows, running water, sewage, electricity or any other amenities and are usually the fourth or fifth born to a mother whose "spouse" is often the second or third in line, works only sporadically, and drinks to excess. As in most parts of the world, the the very poor often have a relative who has managed to "make it" and enjoys a far superior standard of living. Thus, a grandparent, aunt, uncle, or godparent may in some cases take over a malnourished or other child and provide him or her with a superior home environment where, among other things, regular meals and a relatively high standard of hygiene exist. Legalized adoptions and foster homes are a relatively new development in Peru and we have been able to place only a few children whose families had totally disintegrated.

METHODS

The eight study children had been admitted to our unit, severely malnourished, at the mean age of 8.75 months with a mean height *quotient* of 38.9. Arbitrarily using the 50th percentile of the Boston standards (7) actual height is converted to a *height age.* Height quotient (HQ) is height age x 100/chronological age. Weight quotients were much lower but are disregarded, being a poor indicator of growth. As a control for each study child we selected, from all those being followed, the child whose age and height quotient on admission most nearly matched his or hers, sex being disregarded. We came up with eight *control* children with a mean age of 7.75 months and a mean height quotient of 38.9 on admission. Their subsequent linear growth and that of their head circumference had been followed until the mean age of approximately 9 years at the time of this analysis. In line with our last report (5), head circumference in centimeters is related to height, instead of being converted to a quotient. All 16 children had an evaluation of their *intelligence* made by a competent psychologist unrelated to our unit and unaware of their background, using the Wechsler Intelligence Scale for Children, Bender Gestalt (visual-motor), and Draw-A-Person Tests, occasionally replaced by the Standford-Binet (form L-M), all well adapted to Peruvian children.

RESULTS

Table I summarizes the growth of the matched study and control children. The clinical details of the study children and their controls follow.

The first study child, #004, was admitted at the age of 7 months with a length of 59 cm, a weight of 3.5 kg, and a head circumference of 37.5 cm. Her height quotient (HQ) was 42, her height corresponding to that of a 3-month-old girl on the Boston 50th percentile. Her control, #096, was 6 months old, measured 59.5 cm, weighed 4.3 kg, and had a head circumference of 38.2 cm on admission. At the time of discharge #004's HQ was 61; she returned to her own family and at the age of 45 months HQ remained at 60, suggesting severe permanent stunting at a height very far below the Boston 3rd percentile, which corresponds to a HQ of 75 at this age. She then was moved to the far superior home of her paternal grandmother. HQ rose to 70 at 68 months, 79 at 85 months, 84 at 97 months, 91 at 121 months and 95 at 123 months, better than the Boston 25th percentile. Head circumference grew to 43 cm at 13 months, 47.5 cm at 45 months and 52.0 cm at 121 months. Between 4 and 10 years of age the normal increase in head circumference is 2.0 cm (8) while this

TABLE I

Evolution of Height, Height Quotient (HQ) and Head Circumference of 16 Severely Malnourished Infants, the First 8 of Whom Were Transferred to a Much Better Home Environment After Discharge from the Hospital

	On admission					Discharge				Transfer				Latest			
# & Sex	Age mos	Wt kg	Ht cm	HQ	Head cm	Age mos	Ht cm	HQ	Head cm	Age mos	Ht cm	HQ	Head cm	Age mos	Ht cm	HQ	Head cm
004F	7	3.5	59.0	42	37.5	13	68.6	61	43.0	45	88.5	60	47.5	133	142.0	95	53.5
010F	8	3.6	63.0	56	39.8	18	78.8	89	46.9	50	101.5	90	50.5	133	153.2	111	53.5
036F	15	4.3	60.0	20	39.5	50	94.0	67	47.5	88	112.0	73	48.8	124	139.2	98	50.0
037F	15	4.8	61.5	23	38.0	50	92.0	61	45.5	88	110.2	70	46.5	124	139.1	98	48.8
039F	6	4.0	57.0	33	39.5	13	65.6	46	44.7	13	65.6	46	44.7	110	121.7	76	52.0
092F	9	4.7	64.3	61	40.6	19	74.5	66	45.8	41	91.0	72	47.8	88	118.0	86	51.0
095F	7	3.1	60.1	43	38.0	17	73.0	67	45.0	33	87.0	76	47.2	84	117.2	89	51.2
121M	3	3.8	54.3	33	38.0	28	84.9	75	50.2	28	84.9	75	50.2	76	114.5	88	53.0
Mean	8.75	4.0	59.9	38.9	38.9	26.0	78.9	66.5	46.1	48.3	92.6	70.3	47.9	109	130.6	92.6	51.6
096M	6	4.3	59.5	42	38.2	10	63.5	45	41.0					85	109.6	70	48.1
012M	6	4.7	61.0	58	38.0	10	68.2	70	42.5					128	132.4	79	50.5
049M	13	3.6	58.0	19	37.3	36	85.0	60	45.0					114	120.0	68	47.0
045F	12	4.1	61.0	29	39.1	16	65.8	37	42.5					119	125.2	77	49.4
085M	6	3.8	57.5	33	37.8	12	66.5	50	43.0					87	104.0	56	48.5
003F	10	5.6	64.0	55	42.0	16	71.5	65	45.3					140	133.2	78	51.8
084M	6	4.3	59.5	42	39.6	14	71.5	64	44.5					90	112.2	70	50.6
066F	3	3.3	54.0	33	36.7	12	68.7	66	43.7					95	113.9	71	50.5
Mean	7.75	4.2	59.3	38.9	39.6	15.8	70.1	57.1	43.4					107.2	118.7	71.1	49.6

girl's head grew 4.5 cm to attain the exact norm for her age. Her *control*, #096, was discharged at 10 months of age, with a HQ of only 45 but continued to progress and at 19 months reached 61. His progress has been slow and at 85 months has reached 70, a value almost identical to that of the malnourished and their healthy siblings in our previous report (5). At the age of 10 years #004 had an IQ of only 35: it was thought that much of her poor performance was due to poor cooperation and infantile behaviour, possibly the result of pampering and the lack of appropriate stimulation at her grandmother's home. At 6 years of age #096 had an IQ of 68: height age and mental age were almost identical.

The next study child, #010, remained in the hospital until 18 months of age and in the convalescent unit until 28 months of age, HQ increasing from 56 to 96. During 9 months in her disastrous original home this fell to 81; she was admitted for another 13 months and recovered to 90. At age 50 months she was adopted by a middle class family and by age 96 months her HQ had risen to 111, where it has remained for 3 years: this corresponds to the 75th percentile of Boston. Head circumference has remained appropriate to her height at all times, showing similar acceleration and deceleration in growthand IQ was estimated at 82 at the age of 10 years. Her *control*, #012, has had an erratic course at home since discharge at age 10 months with a HQ of 70: this is now fairly stable at around 79. At age 116 months his IQ was 85. Head circumference, though lagging moderately behind height, had grown from 47.5 cm at 46 months to 50.5 cm at 128 months, a gain of 3.0 cm as against the normal of 2.4 cm.

Twin study girls, #036 and #037, were admitted at age 15 months measuring 60 and 61.5 cm (HQ's = 20 and 23) and remained under our direct care until the age of 50 months when their HQ's were 67 and 61 and they were transferred to an asylum for abandoned children. Progress there and in a foster home was slower and they reached HQ's of 73 and 70 at the age of 88 months, when they were adopted by a lower middle-class family. In the succeeding 25 months their rate of growth accelerated markedly and at the age of 113 months their HQ had reached 89. At 124 months it had reached 98, almost the 50th percentile of the Boston standard. Head size, though lagging behind height, and particularly so in one of the twins, grew at a greater than normal rate, 2.5 and 3.3 cm between 50 and 113 months of age. Their IQ's at 113 months were 66 and 61. One of the two control children, also a girl #045, was discharged at 16 months of age while the other, a boy #049, was discharged at 36 months of age. Growth rate was very similar to that of the study girls until 7 years of age, when both had HQ's near 70. The girl has increased to 77 at 119 months, while the boy at 114 months had a HQ of 68. The girl's growth in head circumference has been better, keeping pace with linear growth. Her IQ was 77 at 107 months. The boy's head growth, though at a normal rate since discharge, has not demonstrated significant "catch-up." His IQ was 50 at 102 months of age.

The next study girl, #039, was discharged directly to the home of her godmother and grew at an accelerated rate until the age of 68 months, when her height quotient leveled off at 76, where it has remained until 110 months of age. Growth in head circumference was, if anything, faster and at 110 months was 52.0 cm, having gained 7.3 cm since her discharge at 13 months of age. The normal gain for this age span is 5.8 cm (8). Her IQ at the age of 8 years was estimated at 93, although on the verbal scale it reached 103. One of her male siblings has remained in his original home and at the age of 103 months had a HQ of 66 and an IQ of 78. The control boy, #085, did as well as #039 in the hospital and returned home at 12 months of age. He did very badly for 21 months but then picked up and at 87 months of age had a HQ of 56 and an IQ of 91. Head size, though lagging moderately, is within the normal range (2SDs) for his height. From other studies in his family we feel quite certain that he is genetically destined to be of very short stature, but that he has significant deficit from chronic undernutrition.

Study girl #092 and her control, #003, had very similar growth patterns until the age of 41 months when the first, after having been back in her original home for 22 months, was "adopted" by a social worker. Her height quotient at 64 months was 93, a very striking gain. Head size grew 2.2

cm during this same time, against a normal of 1.1 cm. At 76 and 88 months HQ had decreased to 91 and 86 but head size increased to 51 cm. Her IQ was 110 at 79 months of age. The control girl's HQ remained near 75 for some years and was 78 at 140 months. Her head size is appropriate to her height, and IQ was 84 at 127 months of age.

The next study girl, #095, grew rapidly in the hospital, at home, and eventually in the home of her aunt, reached at the age of 72 months a HQ of 87, an appropriate head size, and an IQ of 72. At 84 months HQ was 89. One of her male siblings, who has remained in his original home at all times, at the age of 86 months had a HQ of 76, a head size which was normal for his age, and an IQ of 70. The control, #084, had a disastrous 21 months at home after discharge, but after the age of 35 months made impressive gains and at the age of 90 months had reached a HQ of 70, with an appropriate head size. His IQ was 62 at 78 months of age.

The last study boy, #121, was discharged to a satisfactory foster home at 28 months of age and continued to grow at an accelerated rate, reaching at the age of 64 months a HQ of 91, a head size normal for his age, and an IQ of 90. At 76 months HQ was 88. The control girl, #066, grew irregularly after discharge and at 83 months had a HQ of 71, a head size appropriate to her height, and an IQ of 80. At 95 months HQ was still 71.

It is of interest that seven of the eight study children were girls, since in our unit male admissions outnumber females by almost two to one. There is a distinct bias towards admission of boys, who are more suited for the metabolic studies carried out. In Peru relatives are more likely to assume the care of a little girl than of a little boy, who might be considered more of a problem as he grows up. In the control group, selected exclusively on the basis of age and height quotient, the ratio of five boys to three girls is normal for our unit.

Radiological bone age has been followed regularly in these children but is not reported in detail. As in other studies, it followed height age very closely (5). None of the girls, despite the fact that some had passed ten years of age, had signs of beginning sexual maturation. For Peruvian mestizo children the average age at menarche is considered to be close to 11 years.

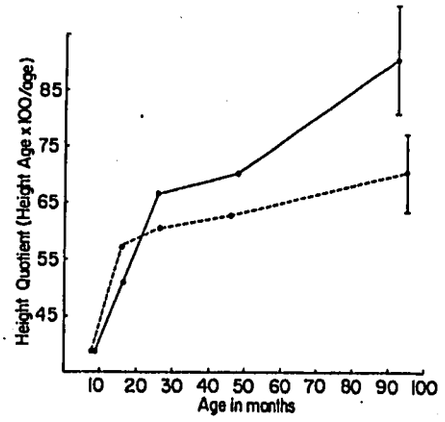

Fig 1. Linear growth of severely malnourished infants, half of whom (solid line) were "adopted" at time of fourth measurement. One SD above and below mean for each group shown at time of last measurement.

Figure 1 represents the evolution of the mean height quotient of each group. The first point on each line represents the mean value on admission, when both were equal but the study children were one month older. The second point for the control children corresponds to the moment of discharge from our care to their original homes, at which time mean age was 15.8 months and mean HQ was 57.1 ± 11.7 (SD). At a comparable age, 16.3 months, the study children, still under our direct care, had a mean HQ of 50.9 ± 13.0. This difference suggests that the growth potential of the control children was as great as that of the study children, since both had been under our care continuously and dietary management was essentially the same.

The third point for the study children represents the mean HQ (66.5 ± 12.3) at the time of discharge from our care, either to their original home or a new one, at the mean age of 26.0 months. At a comparable mean age, 26.3 months, the control children had a mean HQ of 60.5 ± 5.9, having been home an average of 10.5 months since discharge. The much longer hospital stay of the study children was due to the very bad home situation and it is apparent that at least in growth rate they profited from it.

The fourth point for the study children corresponds to the moment of their change to a new environment. At a mean age of 48.3 months their mean HQ was 70.3 ± 12.8. At a comparable age, 45.1 months, the control children had a mean HQ of 62.8 ± 10.8. Progress for both groups during these 20 months had been at a similar slow rate.

The last point for both groups represents the mean HQ at the time of the next to last visit. For the study group, at a mean age of 92.8 months, this was 90.6 ± 9.7 and for the control group, at a mean age of 95.3 months, it was 70.4 ± 7.0. For the first time, the difference was highly significant, with $p<0.02$. At the time of the most recent measurement, not shown in the figure, mean HQ of the study group was 92.6 at 109 months of age. For the control group, at 107.2 months it was 71.1.

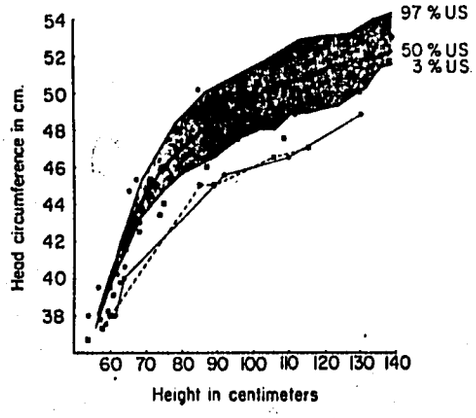

Fig 2. Relation of head circumference to height at the time of each measurement. Circles correspond to "adopted" children, squares to matched "controls". One case from each group (measurement joined by lines) remained consistently below normal range, represented by shaded area.

In Figure 2 the head circumference of each child in centimeters is related to the height in centimeters at the time of each of the measurements summarized in Figure 1. They are contrasted to a *normal* range, based on the 97th, 50th and 3rd percentiles for height at each year of age in the Boston Standards (7) and the same percentiles for head circumference from the universal standard of Nellhaus (8). Although head size on admission was often small for height, by the time of the last measurement all but one in each group fell within the *normal* range. These two, #037 and #049, have been plotted individually to show that head growth has proceeded at a normal rate but without significant "catch-up." This could represent a genetic characteristic but also might be interpreted as a permanent acquired deficit.

The mean IQ of the study children was 76.1 ± 23.0 at a mean age of 8 years. The median was 77. At the same age the mean IQ of the control children was 74.6 ± 13.7 and the median 78.5. With such wide variations the similarity of the mean values is almost certainly fortuitous. There was no correlation apparent between mental age or IQ and height quotient, absolute head size, head quotient, or head quotient divided by height quotient.

DISCUSSION

We have taken considerable liberty in referring to the *matched* children as controls. Ideally, they should have been siblings but these could be found and followed regularly for only two of the eight study children. The difference in sex distribution between the two groups is also striking, The use of height quotients, based on the standard for each sex, partially corrects for this anomaly. In the much larger group from which these children were selected we have not yet detected any sex difference in rates of "catch-up" linear growth.

The *control* children in this study are growing at a rate very similar to that of our much larger group of malnourished children, typified in a previous report comparing them with their so-called healthy siblings (5). The same report documented the fact that the genetic potential of the children being followed was very close to the 25th percentile of the Boston standard (7). This would suggest that the children in the present study, when transferred to a much better home, were able to make rapid advances in linear growth and return to their genetically programmed size or very close to it. Of greatest interest is the fact that they were able to do so at an age when the "catch-up" growth of most children in our own studies and those of others has slowed down markedly, after bringing them to a height which is equal or close to that of their healthy siblings and to that of the population from which they came (5, 6).

In this study, as in our previous report, head size (circumference) in nearly all cases has achieved a dimension within two standard deviations of the mean for height age. In those children whose linear growth accelerated markedly after "adoption" the head kept pace with height, suggesting the existence of an equal potential for delayed "catch-up." If the results of both studies are combined they suggest that the head size of children is a function of their height whether 1) they have been continuously well nourished; 2) well nourished during the first two years of life and then chronically undernourished; 3) severely undernourished during most of the first year of life,

intensively rehabilitated for a few months, and then chronically undernourished; 4) chronically undernourished; or 5) severely undernourished during most of the first year, intensively rehabilitated for a few months, chronically undernourished for up to 38 months, and then well nourished for as little as 23 months. If head size is related to chronological age then groups 1 and 5 only would fall within the normal range and groups 2, 3 and 4 would appear to have deficits in head size resulting from malnutrition. When related to height, probably the best indicator of biological age, all five groups have appropriate head sizes.

The results of IQ estimations were so varied that it is impossible to draw conclusions from them. All we can say is that there has not been an improvement to parallel or match those observed in height and head size. Of the many important factors responsible for measurable intelligence at eight years of age, certainly severe and prolonged deprivation during early life, whether at home or in an institution, looms as most impressive.

SUMMARY

The growth of more than 150 Peruvian children, all severely malnourished in early life, is being followed. Of the entire group only eight have had the benefit of a dramatic improvement in their home environment, either immediately after discharge or within a few years of the same. A *matched* group of children, selected because of a similar age and height at the time of admission, is growing, at home, at a rate below the 3rd percentile of the U.S. standard, suggesting that chronic undernutrition will keep them from attaining their full genetic potential. The eight *favored* children have made dramatic gains in height, beginning as late as the 88th month of life, and at the mean age of 9 years are at the 25th percentile of the same standard. For both groups head size is appropriate to their height age.

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