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Eds. Cravioto's studies have been criticized on the basis that weight and height are imperfect measures of nutritional status. This criticism usually comes from workers in industrialized countries where variations in the height of individuals are more genetic than environmental. This circumstance also holds for middle- and upper-income segments of populations of developing countries. It is significant that Cravioto did not find any relationship between height-for-age and test performance in the higher social classes in Guatemala and Mexico but did find a strong direct relationship among the children of lower socioeconomic groups. The reasons why height- and weight-for-age of children from low-income families in developing countries are a good indication of nutritional status during infancy and early childhood have been discussed in Part Two.

Doubt has been expressed that malnutrition itself is primarily responsible for the association between anthropometric measurements and intersensory integration scores, but rather that the effect is from the adverse educational and social factors usually accompanying malnutrition. Cravioto was obviously well aware of this possibility and looked for an association with family income, housing conditions, proportion of income spent on food, personal hygienic conditions, and parents' education. He had no success. While this does not prove that malnutrition was the primary factor in the children he studied, at least it is strongly presumptive.

The two models presented by Cravioto do not represent the only alternatives. The one that seems most likely is a combination of the two, that is, that both social factors and malnutrition influence intersensory integration independently and also interact with each other to produce that result.

The next paper by Dr. Mönckeberg describes another approach to the problem, the long-term follow-up of children with clinical marasmus.

Effect of Early Marasmic Malnutrition on Subsequent Physical and Psychological Development

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Although several published studies analyze the effect of childhood malnutrition from a biochemical and clinical viewpoint, few consider growth and development after recovery. Whether the effects are permanent or transient is also little known.

Some observations on animals[1,2] as well as humans[3-5] indicate that the effects of malnutrition are more severe and lasting the earlier the process begins and the longer it lasts. Woodruff[6] suggests the existence in man of a critical period during the first months of life when advanced malnutrition acts permanently upon physical and psychological development.

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In Chile malnutrition starts at an early age, due largely to a remarkable decrease in breast feeding during recent years. Poor socioeconomic, sanitary, and cultural conditions[7] do not conduce to good artifical feeding. Frequently infants 6 months to 7 months old are admitted to hospital, weighing little more than at birth and with a gain in height of no more than 3 or 4 cm. Case fatality is great even with good treatment.

Fourteen children with severe marasmic malnutrition were admitted to our metabolic ward. The disease had begun during the first months of life, strongly influenced by adverse social and economic conditions. The children were treated for long periods, then discharged and followed through visits to the outpatient department. Table 1 shows birth weight, approximate age at which malnutrition started, age when hospitalized, and weight and height at the time of admission. After discharge, each patient received a total of 20 liters of free milk per month with a similar amount for all other infants and preschool children in the family.

The children are now aged 3 to 6 years. All appear clinically normal and have a biochemical index of nutrition (hematocrit, hemoglobin, total protein, and albumin) within normal limits. Figure 1 shows anthropometric measurements of the group compared with those for children meeting the Iowa standard. Weight in every case is past the third percentile; height in every case is below that value. The relation of weight to height is above normal, in some cases so much as to give the impression of obesity. For almost every child the ratio of sitting height to total height is more than two standard deviations beyond the average for normal Chilean children (Fig. 2). Values for head circumference are definitely below normal.

Figure 3 demonstrates the present intelligence quotient (I.Q.) of the 14 children. The average value was 62 (Binet method) and in no case above 76. Figure 4 shows the results of the Gesell test. Although the test is valid up to the forty-second month of age only one child was able to reach the limits in all four areas. The best development was usually in the personal-social area, language being most retarded.

Although the children were examined periodically and a high proportion of required protein was provided by the free milk, we cannot be certain that nutrition was optimal during the follow-up period. Nevertheless, weights were normal according to age and even excessive for the short stature of the children.

The results of these physical and psychological tests have led us to conclude that brain damage in infancy is permanent at least up to the

TABLE 1
Fourteen hospitalized malnourished Chilean infants

Case	Sex	Birth wt (kg)	Age of malnutrition (mo)*	Admission age (mo)	Admission wt (kg)	Wt increase (per cent†)	Height (cm)
1	F	3.5	3	6	3.8	8	57
2	M	3.5	3	3	3.2	−16	56
3	M	3.0	2	3	3.3	16	57
4	F	3.2	2	7	4.8	39	57
5	M	3.8	1	3	3.1	−38	53
6	M	3.7	5	7	4.4	17	63
7	F	3.0	1	5	3.1	40	55
8	F	2.9	4	9	4.2	26	58
9	F	3.5	2	4	3.1	−13	57
10	F	3.0	3	5	3.9	30	59
11	F	2.9	2	11	4.2	21	58
12	M	3.1	2	8	4.2	24	58
13	F	3.4	2	5	2.7	−25	53
14	F	3.8	5	11	3.5	−4	61

* Approximate age when malnutrition began.
† The percentage of weight increase is equal to actual weight minus weight at birth multiplied by 100 and divided by the normal monthly weight increase multiplied by age in months.

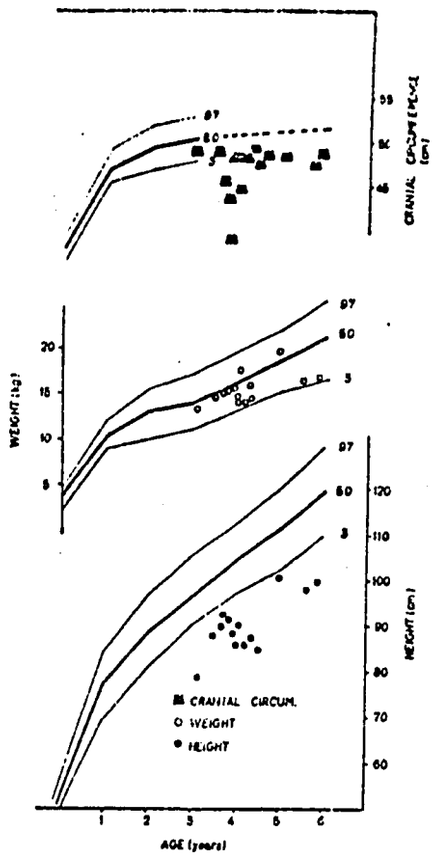

FIGURE 1
Anthropometric measurements of 14 children, malnourished during the first months of life, and deviations from the Iowa Reference Standard.

sixth year of life, despite improving nutritional conditions. The average intelligence quotient of the study group was significantly less than the average of Chilean preschool children of low socioeconomic state (P 0.001).

It is recognized that brain growth takes place primarily during the first months of life[8] and is largely a process of protein synthesis.[9] Thus our observations are in agreement with those described for hypothyroidism, galactosemia, and phenylketonuria, conditions in which the brain is irreversibly damaged during its period of rapid growth.

A number of animal experiments[10-12] demonstrate that malnutrition can modify to an important extent both brain composition and mental behavior.[13-16] Similar effects have been observed after inhibition of protein synthesis in brain tissue of mice.[17] The studies cited suggest that intensity and permanence of brain damage are greatest

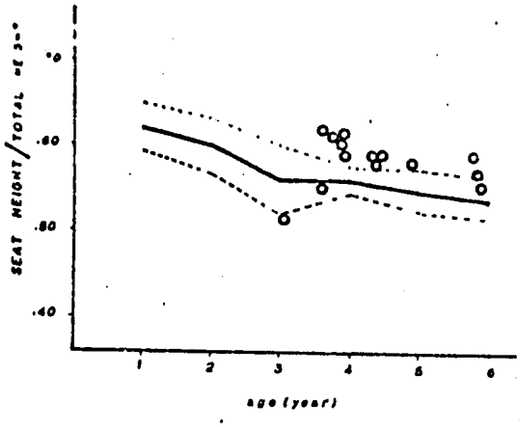

FIGURE 2
Sitting height/total height ratio, 14 children malnourished in the first months of life and the Chilean average (thick line with ±2 standard deviations).

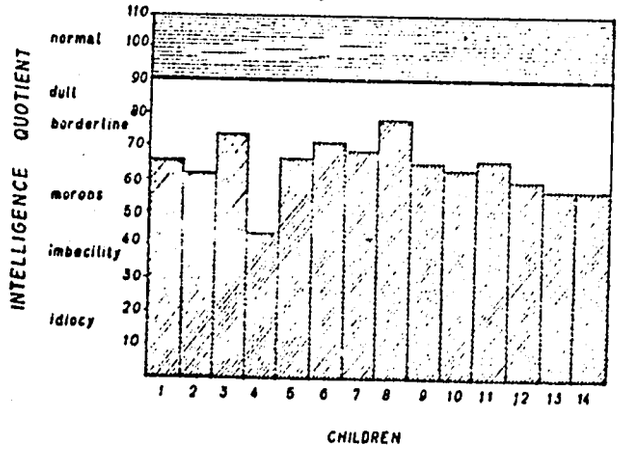

FIGURE 3
Intelligence quotients of 14 children with marasmic malnutrition in infancy, hospitalized until recovery and observed thereafter, present ages 3 to 6 years.

among children malnourished at an early age. Cravioto remarks that an intelligence quotient deficit in malnourished preschool children is regained as nutrition returns to normal, provided the child lives in an adequate environment.[9] This too suggests an early critical period, probably the first months of life, during which brain damage tends to be more severe and lasting, and a later period during which damage is temporary.

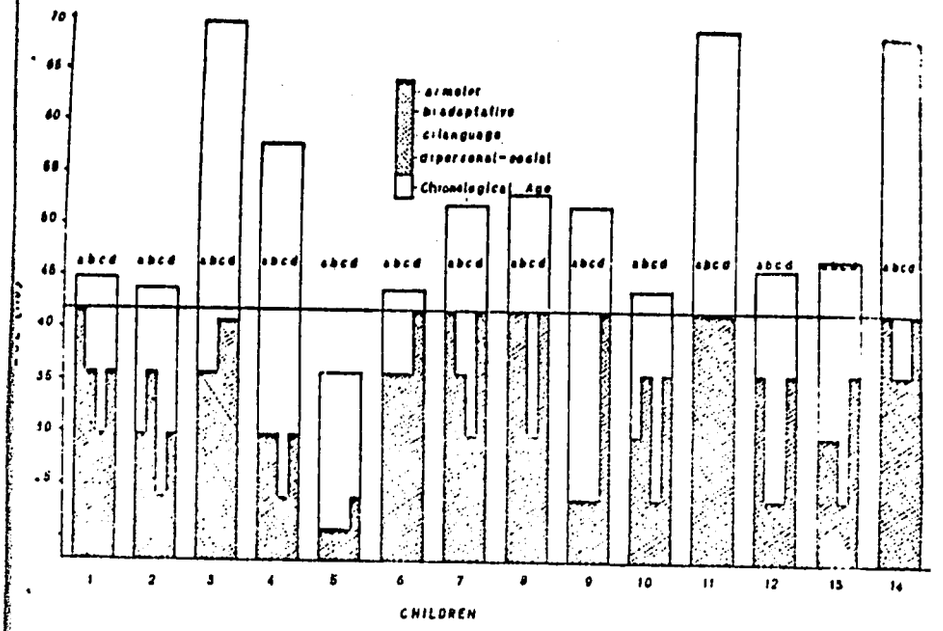

FIGURE 4
Gesell test of 14 malnourished children after nutritional recovery.

Evidence exists that in an economically depressed population, preschool children of the same age but different nutritional state experience different motor development.[18] Children suffering from malnutrition also usually come from homes where economic pressures restrict adequate stimulation for mental development. Thus it seems obvious that the high frequency of mental retardation in these segments of the population is not merely the consequence of malnutrition.

A high incidence of malnutrition was observed in a recent nutritional survey of 2,300 infants and preschool children in the province of Curicó. Malnutrition began during the first months of life[19] (Fig. 5). An associated feature was a lesser average value for head circumference relative to the Iowa standard (Fig. 6). A relation between head circumference and mental retardation has been observed.[20]

The influence of social class and of malnutrition on the frequency of psychological deficit was determined in another study of 153 preschool children within three social groups. Group A included middle-class children, and Groups B and C were lower-class. Groups B and C had the same average income per capita, a similar low

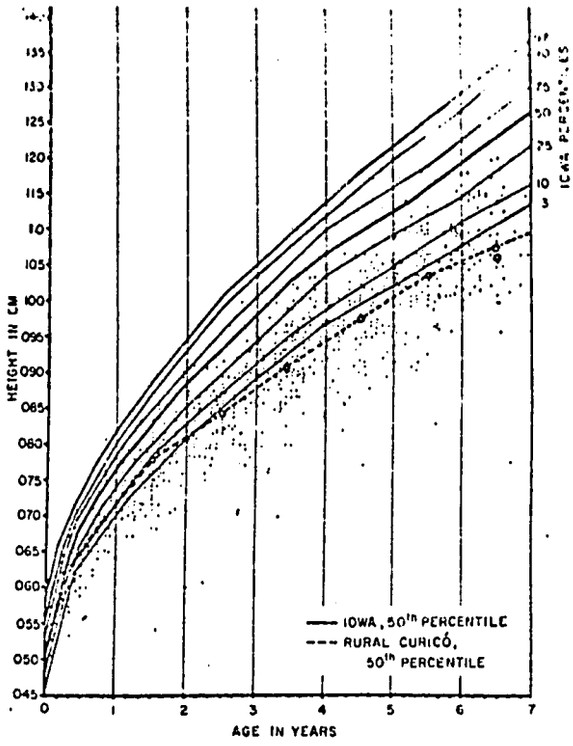

FIGURE 5
Height of 960 nursing and preschool children from province Curicó, Chile, and from Iowa, U.S.A.

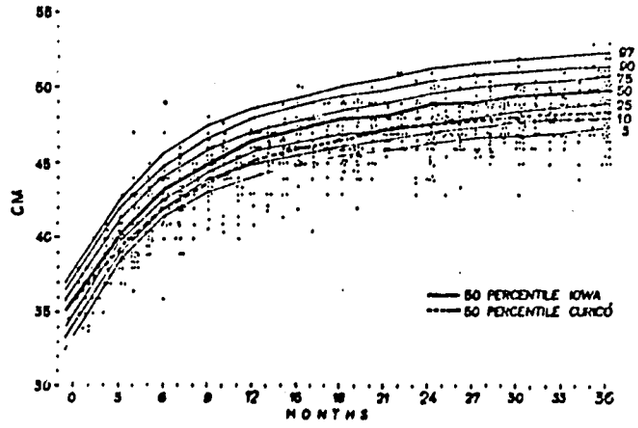

FIGURE 6
Head circumference of children from province Curicó, Chile.

educational level of the parents, but differed in nutritional state. Group B was from a population with no malnutrition, due to free distribution of milk and free medical assistance during the last 10 years. Group C had a high incidence of malnutrition in children of preschool age.

Figure 7 shows proportions of children in the three groups who had normal psychological development. Groups A and B are essentially equal and at a high level, while in Group C only 50 per cent are normal. A supplemental feeding program, however, acts on the environment and on maternal motivation as well as nutritional state, with the result that the two lower-class groups probably differ in several respects.

Figure 8 gives further information on Group C children. Psychological development was determined by the Gesell test. The children were divided into three groups according to height, on the assumption that children experiencing the more prolonged and sustained malnutrition would show the greater retardation in growth. The separate Gesell test areas show different grades of subnormality, especially in children below the tenth Iowa percentile. However, the group of well-nourished children in poor socioeconomic circumstances also included a high proportion of subnormal individuals.

The observations indicate that early malnutrition tends to restrict expression of the genetic potential for development, both physical and psychological. Socioeconomic factors also strongly affect mental development and cannot be separated satisfactorily from nutri-

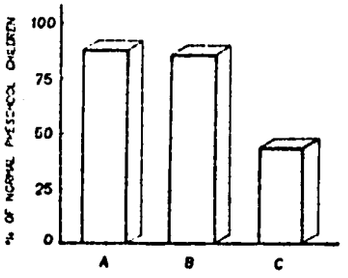

FIGURE 7
Preschool children of normal psychological development, by social groups. A: Chilean middle-class. B: low socioeconomic group with no malnutrition. C: low socioeconomic with much malnutrition

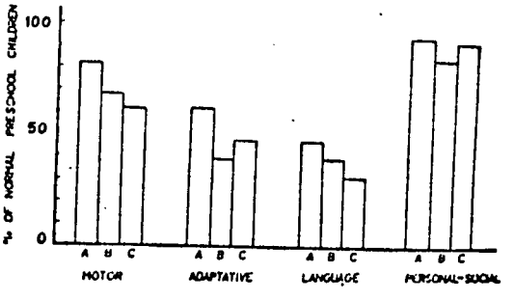

FIGURE 8
Gesell test in preschool children of a malnourished, low socioeconomic group. A: height more than twenty-fifth percentile Iowa reference standard. B: height between twenty-fifth and tenth percentile. C: height between tenth and third percentile

tional influences. The early onset of malnutrition in Chile further complicates the problem. Breast feeding becomes less frequent and of shorter duration, as in other undeveloped countries.[21] Malnutrition thus develops earlier, in the first months of life, and at a more critical stage in brain development.

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Eds. *Mönckeberg cites evidence that, compared with other low-income children of comparable age from the same population, those who suffered early marasmus do not catch up in I.Q. and Gesell test performance by 3 to 6 years of age. This was true even though special efforts were made for their continuing nutritional rehabilitation and follow-up. The effect of early marasmus is likened to the effect of congenital metabolic defects such as phenylketonuria and galactosemia; this may be an appropriate analogy. If the effect on mental development were not a lasting one, the special attention which the children received might well have had the opposite effect; that is, they might have scored better than other children in this underprivileged population. The lesser head circumference of the children with early marasmus is compatible with a smaller brain size.*

Mönckeberg is acutely aware of the possible confounding effects of social factors but does not believe them to be primarily responsible for the observed differences within the lower socioeconomic group he studied. In the next paper Drs. Stoch and Smythe describe a study in South Africa in which large social and environmental as well as nutritional differences distinguished groups of "malnourished" and "well-nourished" children.

Undernutrition During Infancy, and Subsequent Brain Growth and Intellectual Development

Mavis B. Stoch, M.B., Ch.B., and P.M. Smythe, M.D., F.R.C.P. (Lond.)
Red Cross War Memorial Children's Hospital and The University of Cape Town
Cape Town, South Africa

Twenty Cape Coloured infants, grossly undernourished in infancy, were followed for 11 years.[1] They were compared periodically with matched controls for head circumference, height, and weight. Intellectual and psychological assessment and electroencephalograms showed that undernutrition during active brain growth resulted in reduced brain size and impaired intellectual development.

The study, which started in 19[illegible], was based on the hypothesis that the ill effects of undernutrition are determined by (1) its occurrence during the period of maximum growth and (2) the duration of undernutrition relative to the total period of growth.

Since brain growth in man is greatest in the first year of life and almost complete by the end of the second year (Fig. 1), it seemed reasonable that undernutrition during this period could inhibit brain growth, result in permanent reduction in brain size, and restrict subsequent intellectual development. Previous investigators had stressed that the brain is spared during undernutrition, but all studies were of individuals more than 2 years old, by which time brain growth is almost complete.

Severely undernourished infants were selected for study because, with so many factors conceivably influencing intellectual development, it seemed that only by observing extreme examples would significant differences become apparent. In the report on the first 5-year follow-up, which appeared in 1963, measurements of the head circumference and intelligence quotients of the parents were also recorded. No significant difference was found between the two groups.[2]

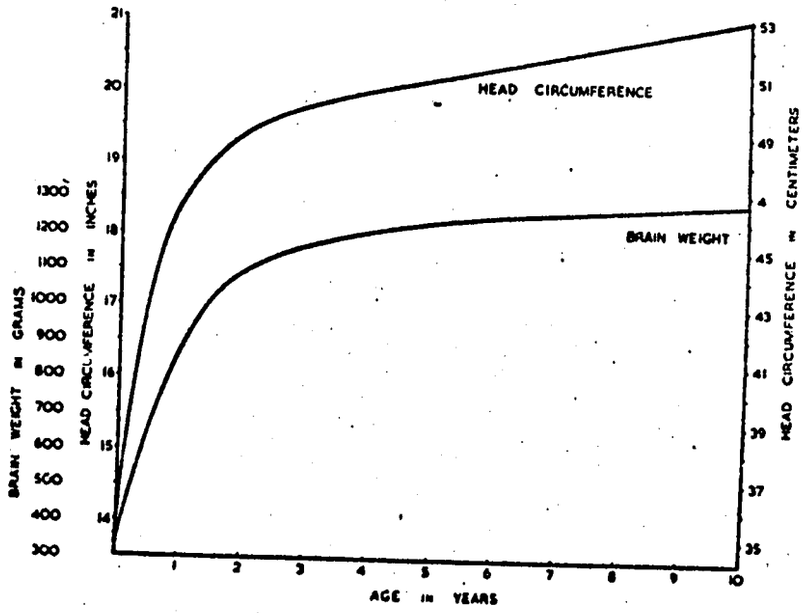

FIGURE 1
Brain weights of children, by age in years.