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APPLICATION OF NEWER KNOWLEDGE OF NUTRITION ON PHYSICAL AND MENTAL GROWTH AND DEVELOPMENT

Joaquin Cravioto, M.D., M.P.H.

DURING the last decades there has been a fairly large number of reports on the effects of nutrition on growth, so by necessity this presentation will tend to be selective and concentrate on certain topics that are important for demonstrating the urgency of preventive measures or of further research.

Observations of growing infants have confirmed that parental size, parental body build, and nutritional status are the main determinants of growth and size.

In general, tall parents have long children; this is the case even at birth. When parental statures are arranged in three categories according to their size, it is easy to see considerable differences in the children of two short, two medium height, or two tall parents. Rarely is the child of the short by short mating above the upper limit of the medium by medium couple; similarly, very seldom is the child of the tall by tall mating below the lower limit of the medium by medium combination.[1] Bayley has shown that as the child grows older there is an increasing correlation between his height and that of the parent of the same sex.[2] The Fels Research Institute's longitudinal study has cross-validated the parent-child relationship but not the sex specificity found by Bayley[3] (Tables 1 and 2).

Through the use of the radiographic measurement of the bony chest breath, as an indicator of the fat-free mass, Garn has shown that children of the phenotype large by large are not only heavier during the growing period, but also taller than children from the small by small mating combination.[1] Bone development also shows a difference in favor of the children of the large by large group, who turn out to be advanced over the progeny of the short by short group in scores on the Gesell, Merrill-Palmer, and Binet Tests[4,5] (Table 3).

It is well-known that underfeeding affects the weight and the size of different organs to a varying extent; the ultimate pattern depends on the period of growth at which undernutrition begins.

Leicht's analysis of the data of the Carnegie-United Kingdom Dietary and Clinical Survey showed that crestal height, as a measure of leg length, was a better indicator of expenditure on food than either total height or weight. In other words, the difference in leg length between groups varying in expenditure of food was greater than the difference in either body height or weight.[6] The influence of deficient nutrition on changes not only in size but also in development or maturation is readily seen in biochemical parameters.

During the entire development, from the fertilized ovum to the full-term infant and from the infant to the normal adult, the biochemistry of the organism changes progressively; growth is associated with an evolving pattern of body composition.

The concept of development implies that the chemical composition at each age brings about changes which cause the tissues to progress one step further toward maturation. At the same time the chemical internal milieu at each stage and the mechanisms that tend to keep it constant are those best suited

Table 1—Correlations Found by Bayley Between the Heights of Parents and Children of the Berkeley Study[2]

Age	Boys No.	Boys Fathers	Boys Mothers	Girls No.	Girls Fathers	Girls Mothers
1 month	24	0.30	0.05	26	0.36	0.30
3 years	25	0.45*	0.25	24	0.38	0.67†
6 years	24	0.52†	0.35	24	0.26	0.75†
10 years	23	0.60†	0.37	24	0.24	0.72†

* Significant at 0.05 level for two tails.
† Significant at 0.01 level for two tails.

for survival under the existing conditions and may not permit continuing maturation.

Studies on the effect of deficient nutrition on biochemical maturation, initiated almost 100 years ago, have been extended during the last 15 years, particularly through the work of McCance and Widdowson, whose studies on several animal species show that undernutrition, even if severe enough to hold the weight of an animal to an extremely low figure, does not prevent some of the developmental processes from going forward to some extent. At the same time food restriction not only arrests some of the changes associated with aging but even reverses some of them, so at the end of the restriction period the chemical structure of the organs may resemble those of a much younger subject.[7-11]

Some organs and some tissues are more readily affected than others. The extent and type of change is associated with the degree of development reached before the initiation of the restriction period.

Perhaps the brain is one of the best illustrations of the fact that, even in a single organ, different components are affected to a different degree. Under severe food restriction, the brain continues to grow in size, increasing its absolute weight and showing normal increments in nitrogen and phosphorous content. The concentrations of Na, K, and Cl, however, correspond to those found in normal animals of a much younger age.[9]

Most of the changes in biochemical growth and development produced in experimental animals are present in infants and children affected by severe chronic malnutrition.[12-16] The degree of reversion of some biochemical processes of normal development is illustrated by Dean, who has documented the reproduction in the malnourished child of features of inborn errors of

Table 2—Correlations Found by Kagan and Moss Between Child's Height and Height of Parents[3]

Age	Boys No.	Boys Fathers	Boys No.	Boys Mothers	Girls No.	Girls Fathers	Girls No.	Girls Mothers
Birth	34	0.36*	28	0.28	24	0.02	27	−0.02
3 years	91	0.45†	84	0.20	60	0.53†	76	0.46†
6 years	75	0.44†	68	0.33†	59	0.51†	65	0.40†
10 years	60	0.47†	57	0.36	49	0.34*	56	0.25

* Significant at 0.05 level for two tails.
† Significant at 0.01 level for two tails.

Table 3—Comparative Skeletal Development of Children of Large-Chested (LL) and Small-Chested (SS) Parents[4]

Skeletal Development	Males LL	Males SS	Females LL	Females SS
Number of hand-wrist centers at 1.5 years	7.8	6.3	18.6	15.2
Number of hand-wrist centers at 3.0 years	22.1	18.4	24.4	23.5
Hand-wrist completion age	6.7	7.7	7.3	8.0
Bone age at 11.0 years	11.9	10.1	10.0	11.1

metabolism affecting histidine and tyrosine, as well as the one responsible for phenylketonuria.[17]

The implications of this arrest in maturation are easily seen in reports showing that malnourished infants respond abnormally to certain stimuli, well tolerated by better nourished infants of the same chronological age.[18]

Pediatricians and general practitioners are well aware of the difference in response to therapeutic agents that characterize the fetus and the newborn infant and the need for the adequate testing of therapeutic products not only in adult animals and human beings but also in pregnant and newborn subjects. In places where infant malnutrition is prevalent, the public health worker and the practitioner of medicine will recognize that some of the differences in response are a function of size and can be eliminated by proper correction for body weight. However, the differences due to arrest in biochemical maturation, and consequently in homeostasis, where chronological age or size are no longer good guides, will also have to be taken into consideration.

Although there is plenty of evidence to the contrary, it has been erroneously believed that the administration of unlimited food abolishes the abnormal characteristics of subjects whose growth has been held up, even for long periods.

Studies of the rehabilitation of severely malnourished infants confirm the more extensive animal experiments. After a child has recovered from kwashiorkor his size remains small and the skeletal development retarded. Biochemical changes in muscle and skin composition are present for at least several months after rehabilitation.[19,20]

Pediatricians and research workers have often been misled by the fact that the rate of change in size is very fast at the beginning of the rehabilitation period, sometimes it doubles or triples the normal rate for the chronological age but later on it slows down. If observations are continued for a longer period it becomes apparent that the initial rate is the one corresponding to the actual size of the child and that later on it goes on with the periodic accelerations and decelerations of normal growth but with a time lag in comparison to the well-fed child. Puberty makes its appearance and growth ceases at the usual chronological age, giving as a net result an undersized and underdeveloped adult. Thus it appears that the rate of body growth is dependent on size, while the duration of growth is controlled by time.

It was previously mentioned that undernutrition retards certain aspects of the chemical development of the central nervous system. Why is it then that so little emphasis has been given to studies of the influence of nutrition on mental development? The principal question is: Does the degree of malnutrition which produces retardation of somatic growth and biochemical development also produce transient or permanent retardation of mental development?

Preliminary attempts to explore quantitatively the relationship between nutritional status and performance on psychological tests have been made on

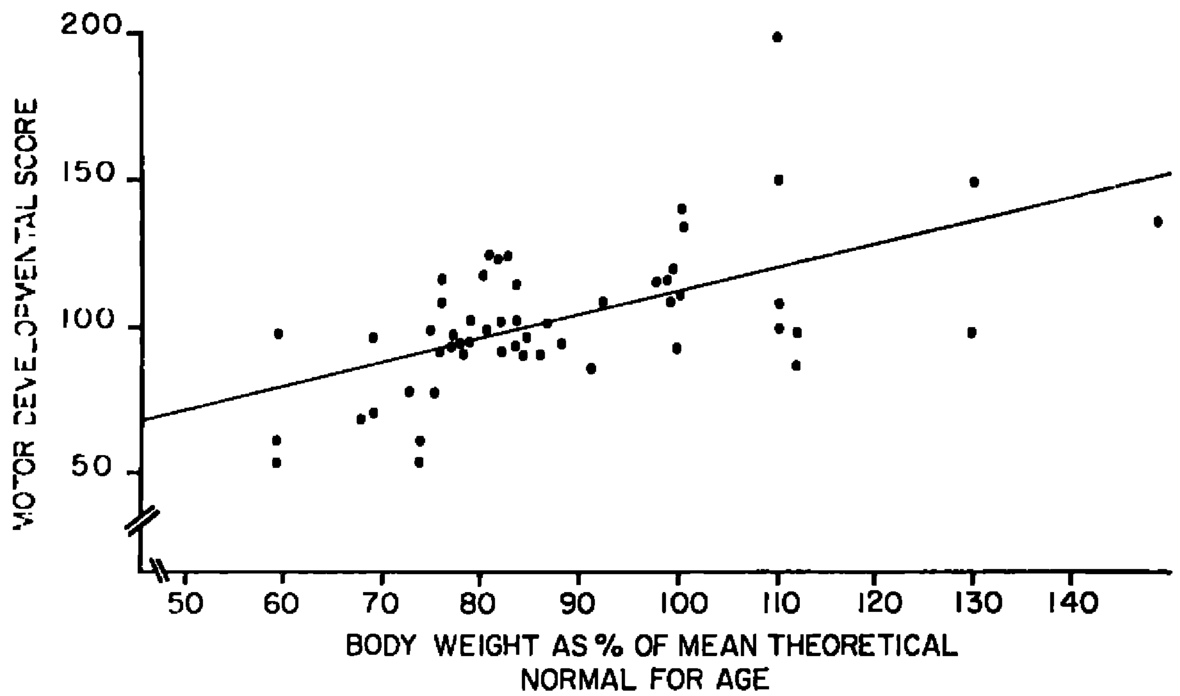

Figure 1—Relationship Between Motor Development and Body Weight

children in Uganda, Mexico, and Guatemala. Infants in these preindustrial countries, when tested by the Gesell and Thomas methods, are in a more advanced state of psychomotor development at birth than North American and European infants. The Gesell stimuli usually considered the elicit responses only after the first month of life are suitable for younger African, Mexican, and Guatemalan children because their development at two or three weeks of age often is equal to that of Western European children two or three times as old. Soon after birth, however, these infants from preindustrial areas show a progressive decline so that by the age of 18 to 24 months their developmental scores are inferior to those obtained by their European counterparts.[21-25]

Even children who later develop kwashiorkor usually grow well during the first months of life. Later on, because suitable supplements are not added when the mother's milk no longer supplies the infant's requirements, weight and height increments begin to diminish. When the child is completely weaned, which usually is late, around the 18th to 24th month, height is practically stationary and weight may even show a slight decrease. If the data for somatic growth are plotted against the mental scores, the direct association between the deficits in height and weight and the developmental scores becomes apparent[23] (Figures 1 and 2).

In five different communities—in

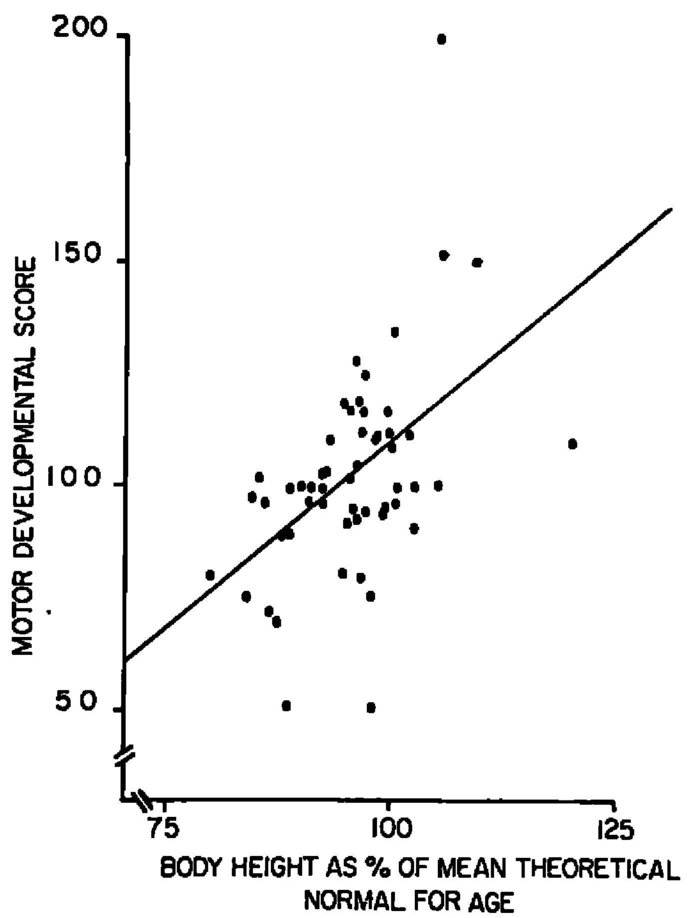

Figure 2—Relationship Between Motor Development and Height

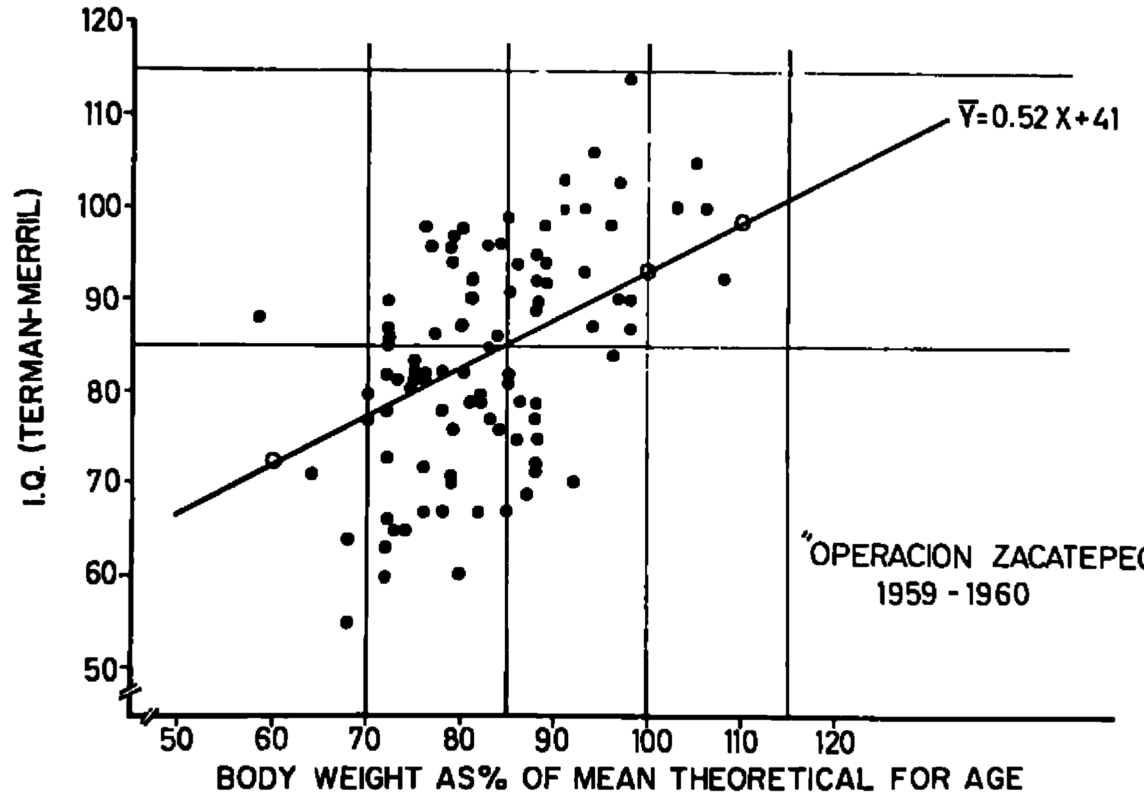

Figure 3—Relationship Between Body Weight and Intelligence Quotient in 96 Preschool-Age Children

Mexico two of typical mestizos, one of Zapotec Indians, one of Nahoa Indians and in Guatemala one of Cakchiquel Indians—high correlations between deficits in height and weight and developmental scores were found. No association of statistical significance could be demonstrated between mental score and cash income, crop income, parental education, parental hygiene, or type of housing. The influence of parental attitudes toward education is at present under investigation in Guatemala.

Terman-Merrill tests, adapted to the local conditions, have been administered to preschool-age children living in a village where malnutrition is so prevalent that no child escapes from at least a mild degree of it. The mental scores were negatively related to chronological age. The older the child the poorer the performance relative to his age. As in the younger group explored with the Gesell method, body weights and heights were found to be positively correlated with the intelligence scores[26] (Figure 3).

After standardization of the Goodenough-Draw-a-Man-Test in groups of school children in a good state of health and nutrition, intelligence quotients were obtained by this method in children attending a primary school in a village with a high incidence of protein-caloric malnutrition. Once again, weight deficit, which may be considered as an indicator of nutritional status, and intelligence quotient were inversely related, so that as the weight deficit for age increased the mental performance decreased.[27]

Children admitted to the Hospital Infantil of Mexico because of severe protein-calorie malnutrition gave very low developmental scores.[28] Results of retesting at two-week intervals during successful treatment revealed that as recovery took place the difference between chronological age and mental age showed a progressive decrease, except in those children whose chronological age was less than six months at the time of their hospital admission. These groups of young infants did not improve their performance, so that the increment of mental age was equivalent to the number of months of treat-

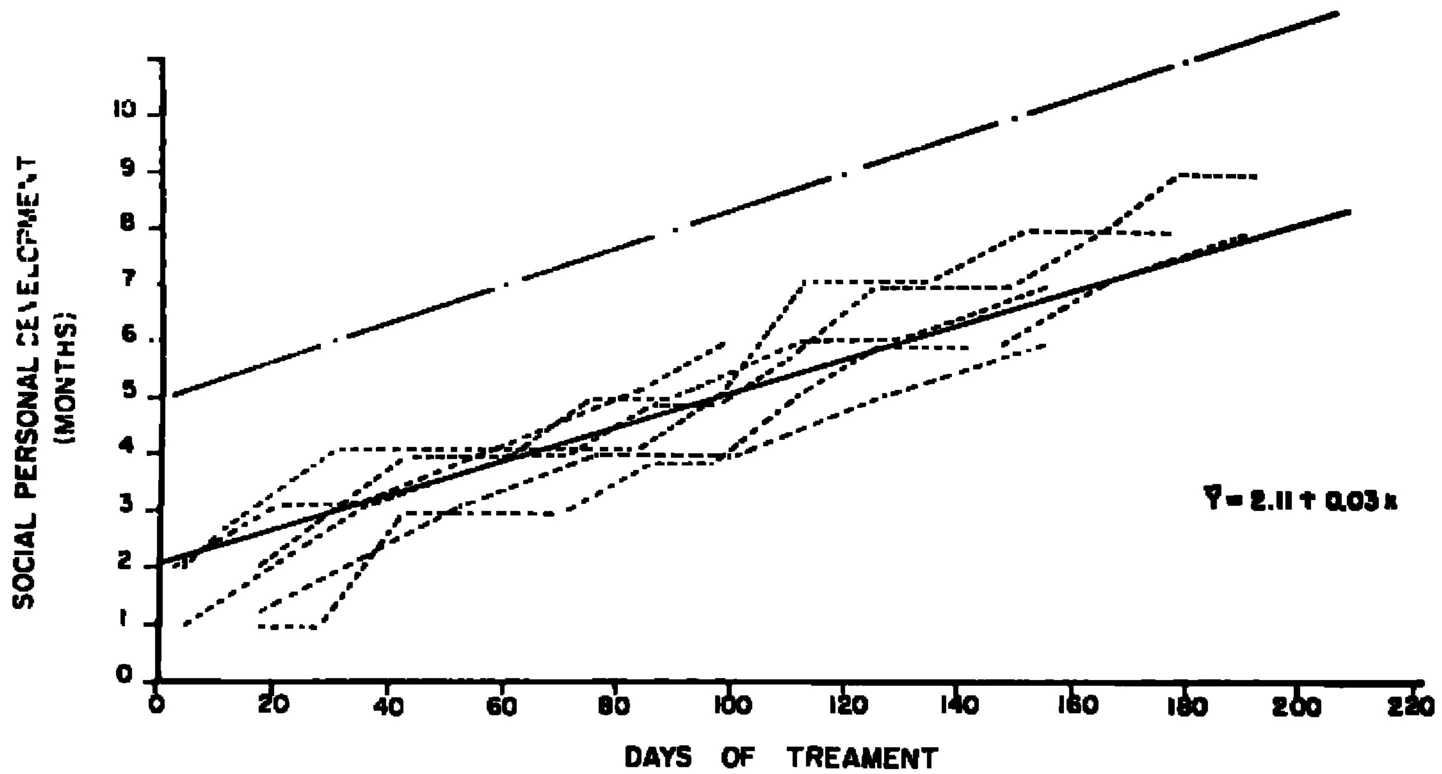

Figure 4—Changes in Psychomotor Development of Infants Less Than Six Months of Age During Recovery from Severe Protein-Calorie Malnutrition

ment (Figure 4). These findings suggest that nutritional rehabilitation is less effective in producing mental recovery in the younger individuals.[29] In the Minnesota experiment of Keys and co-workers, the undernourished adults had completed the development of their nervous system and showed only a decrease in mental activity without a loss of actual mental capacity. Consequently, when they were refed, complete recovery of mental performance was observed.[30]

Any attempt to measure the influence of nutrition on mental performance must consider of necessity the role played by parental factors, such as maternal concern with intellectual development, maternal deprivation, and parental level of intelligence. The relative weightings to be given to parental factors depend upon a series of other environmental conditions. For young children in preindustrial countries food consumption and its consequence, nutritional status, is one of the most important.

For many years nutrition research in preindustrial countries has been concerned with studies of severe malnutrition of the kwashiorkor or marasmus type with the major goal a substantial reduction in the mortality rate from this condition. Programs for socioeconomic development, such as the Alliance for Progress, have as one of their targets to reduce by one-half the present mortality in children below five years of age. As Scrimshaw has pointed out, most deaths in the one- to four-year age group are associated with malnutrition, that is, they are due to the synergism between malnutrition and infection,[31-33] but it is extremely important to remember that the majority of cases of malnutrition do not die.

Perhaps the most important implication of the relation between nutrition and growth and development lies in the fact that growth potential cannot be speeded up and slowed down, as one can accelerate or retard a chemical process, and still get the same result at the end. If one does not use the full potential at all ages one does not get full development. One may get the same ultimate weight but will end with an undersized subject who is abnormal in shape and composition, and may possibly be of a lower mental capacity.

In an increasingly complicated world of sophisticated technology in which even a mild reduction in mental performance may be a serious handicap, the possible effect of early malnutrition on mental capacity and personality development should be a major consideration.

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Dr. Cravioto is associate director, Institute of Nutrition of Central America and Panama, Guatemala City, Guatemala.

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