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NUTRITION, PHYSICAL GROWTH AND MENTAL DEVELOPMENT

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NUTRITION, PHYSICAL GROWTH AND MENTAL DEVELOPMENT*

INTRODUCTION

Protein-calorie malnutrition (PCM) today is under serious consideration as a determining factor in mental development. The problem is of present importance and urgency because of the number of infants and young children in developing countries suffering from some degree of PCM. The severe nutritional illnesses of kwashiorkor and marasmus are within this group, but they represent less than 3% of underfed children in developing countries. The mild to moderate chronic forms of PCM affect 60 to 70% of all preschool children in those countries, and they number approximately 400 million (7). This situation coincides with a time in human history when individual skills, physical fitness and good mental capacity are increasingly necessary to implement technological advances in the developing countries, in order to compete with those achieved in well developed countries. Therefore, if the situation goes unchecked, the already existing gap in training and skills between developed and underdeveloped countries will continue to widen. What would the resulting situation be? Underfed, undertrained, and undereducated people in the world will further increase in number, rendering any contacts with the remaining favored societies even more difficult. In other words, we may be witnessing a situation in which approximately two-thirds of the preschool children in the world are becoming mentally handicapped due to PCM.

A shrinking availability of food per capita, brought about by the rapidly growing population, is one of the factors responsible for the condition described. This compounds the problem. Even with the strongest determination to face the existing situation, establishing whether children already born are handicapped in

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a reversible or irreversible fashion is an extremely difficult task. In its totality, the problem is formidable, for the implications of and approaches to each situation are different every time.

HISTORY AND BACKGROUND

Experimental Studies on Animals

An impressive volume of evidence shows that in experimental animals, diet modifies physical growth and maturation. Some of the landmarks are:

Working with rats, Kennedy (33) showed that undernutrition at early ages produced smaller adult animals than similar counterparts fed an adequate diet. Stewart and Plat (40), studying pigs receiving a protein-restricted diet, demonstrated retarded bone growth in comparison with animals subsisting on an adequate diet. Depending on age at onset, some changes were reversed by subsequent protein supplementation.

Biochemical maturation also may be affected in severe malnutrition. Ross and Batt (39) found the relation between enzymatic activity, chronological age and dietary intake in rats so well defined, that it was possible to predict levels of various hepatic enzymes from the dietary history and age of the rats.

More specifically, in relation to the central nervous system (CNS), Dobbing (17, 18) found that prolonged PCM in rats and pigs produced a reduction of cholesterol and phospholipids in about the same degree as for brain weight. However, lipids specifically enriched in myelin (cerebrosids, proteolipids and plasmalogens) are reduced to an even greater degree than brain weight. This suggests that severe malnutrition affects the process of myelinization of the CNS during early stages of development to make it more vulnerable to injury. Benton _et al_ (8) demonstrated that the decreased myelin components correlated with a decrease of myelin demonstrated by histological techniques. Chase and co-workers (13) showed that severe nutritional deprivation in young rats was associated with a decrease in synthesis of sulphatide both _in vivo_ and _in vitro_. This defect was not corrected by re-feeding. The authors concluded that the time of active myelin formation was a nutritionally vulnerable period in the development of the CNS.

In relation to behavioral changes produced by malnutrition, Barnes (3), working with rats, demonstrated that severe PCM in early life resulted in long-lasting behavioral changes, including what he interpreted as retarded ability to solve complex problems. More recently, Barnes (4) showed that while moderate nutritional deprivation in early life may result in permanent alterations in certain behavioral changes, complex problem-solving appeared only to be affected in cases of severe PCM.

Work with Man

Many studies have also been conducted on the effects of PCM on the mental development of children. Mainly using the Gesell scales, Gómez and co-workers (25) in Mexico in 1954, suggested that different forms of PCM were accompanied by altered behavior and personality. Also using the Gesell techniques in Africa, Geber and Dean (23) in 1956 reported similar findings. In Mexico, Robles and co-workers (38) demonstrated long-lasting behavioral changes in patients suffering severe kwashiorkor and marasmus. Also using the same

Gesell methods, Barrera Moncada (5) in Venezuela, followed children with kwashiorkor and marasmus for several years after their recovery. Seven years later, performance in all tested areas was poorer than among comparable children of the same genetic origin who had not suffered malnutrition.

Cabak in Yugoslavia (11) found permanent decrements in mental performance of children after several years following clinical recovery from severe PCM (marasmus). Stoch and Smythe (41) in South Africa, following groups of children belonging to two contrasting social classes with different nutritional status during a seven-year period, found marked differences using the Gesell, Merrill-Palmer, and a modification of the Simon-Binet Intelligence scales as a measure of their mental performance. Finally, Cravioto and co-workers (15, 16) reported retardation in the development of intersensory integration among malnourished children in Mexico and Guatemala.

On the basis of all these findings, it is logical to conclude that in developing countries, malnutrition could be a common factor responsible for retardation of physical growth and poor mental performance.

CONCEPTS AND DEFINITIONS

Definition of Malnutrition

What is the meaning of the terms malnutrition, undernutrition, protein-calorie malnutrition? Are similar terms expressing the same concept?

Whatever the term, malnutrition in its many forms is a phenomenon determined by multiple factors, closely related to numerous economic and social conditions. When viewed from this complex perspective, the problem of the investigator becomes not that of absolutely isolating the effects of malnutrition _per se_, but of demonstrating the effects of malnutrition as it interacts with the other variables of the "poverty syndrome" (34).

In most of the preceding field studies, designed to explain the effects of malnutrition on mental development, the main emphasis was on food availability and food intake. With few exceptions, however, the great majority of the populations concerned suffer from cultural and educational deprivation, "_social malnutrition_", in addition to economic deprivation, and these factors relate intimately to PCM. The problem of separating the effects of cultural and educational deprivation from the possible effects of PCM on mental development of an individual is rather complicated, as all these elements affect mental performance. Therefore, any thorough investigation intended to demonstrate the importance of nutrition on mental development must take into full consideration all possible factors recognized as bearing on mental development. Otherwise, the results cannot be properly interpreted.

Developmental Periods of the Central Nervous System

In general, the development of the CNS undergoes three different periods: a) neural development, which is accomplished very early in mammals and man; b) development of the oligodendroglial cells, occurring soon afterwards; and c) myelin lipid formation, which is manufactured by the oligodendroglial. Theoretically, it is important to consider that the effects of malnutrition in man may vary depending on the developmental period in which it occurs.

The time peak of appearance of the developmental stages of the CNS differs according to the species and in relation to their birth. For example, myelin lipid formation in guinea pigs occurs at 20 days before birth; in rats, at 11 days after birth and in man during the last 6 to 8 months of pregnancy (18). This myelinization period in man is followed by very fast brain growth rate during the first months of extra-uterine life. Finally, the brain does not grow at a standard rate in its early development; on the contrary, there are "brain spurts". If periods of maximum brain growth coincide with periods of malnutrition, there is an increased possibility that brain development may be irreversibly affected. However, if malnutrition, even in a severe and long-lasting case, were to occur at a time when brain development was completed, there may be no changes produced in brain composition or function (10).

Intrauterine Factors

Central nervous system development in man occurs most rapidly during the last 6 to 8 months of pregnancy and the first two months of extra-uterine life. Factors which retard intrauterine growth may also alter CNS development. The causes responsible for intrauterine growth retardation are: a) fetal malnutrition due to maternal malnutrition or, more frequently, to placental insufficiency and b) fetal malformations.

In well developed countries, numerous cases of severe fetal malnutrition occurred only during serious world crises such as famine, war, etc. There is still not sufficient evidence to prove that children born during these periods were mentally handicapped due to alterations in CNS development. In the case of inborn errors of metabolism or other type of fetal pathology, not directly due to malnutrition, there is evidence that they could be responsible for these alterations. Thus, the alterations in performance observed in children of the developed countries are mainly due to fetal malformations and placental insufficiency, and not to fetal malnutrition resulting from maternal malnutrition (19).

It is a common assumption that in impaired mental function due to malnutrition, the earlier the onset, the longer the duration and the greater the severity, the greater the damage to the brain. However, what is early? Must we consider the uterine environment? Are we becoming more appreciative that mental handicaps occur in children in the course of intrauterine growth without subsequent physical growth impairment? What happens if the mother is malnourished before she becomes pregnant, with that state continuing through gestation?

Recent placental studies still underway in rural areas of Guatemala where malnutrition is prevalent illustrate the point of intrauterine factors and the possible effects of malnutrition on fetal development.

The information previously mentioned points to the fact that the crucial period for PCM to have a direct effect on brain function could be during the last three months of pregnancy and the first six months of extra-uterine life. It is likely that after these critical developmental periods, socio-cultural factors are mainly responsible for the poor mental performance observed among children in developing countries. Late preschool and school ages are of lesser importance. Thus, our efforts to demonstrate brain function impairment directly due to malnutrition is focused in psychophysiological responses obtained during the first twelve months of life. Mental performance after this period becomes socially conditioned.

Therefore, the main efforts to prevent the direct effects of PCM on mental development must be concentrated during pregnancy and the first year of life.

WORK AT INCAP

The staff of the Growth and Development Unit at the Institute of Nutrition of Central America and Panama (INCAP), has been engaged during the past three years in a long-term prospective field program studying the effects of malnutrition on physical growth and mental development.

IDENTIFICATION OF VARIABLES

What are the main variables in the problem? Is quantification possible? Is it worthwhile to begin so complex a study before identifying the possible principal causative factors?

A major difficulty arose in developing methods of measurement serviceable under field conditions. Methods of proven reliability under modern clinic and laboratory conditions are not always transferable to the field. In some instances, no tried procedure existed. The futility of collecting information with lack of quantitative value led to a decision to accomplish that aim, even if we never moved into the definitive investigation. The objective has been attained. We have identified the three main variables

State of Nutrition (Independent Variable)

The state of nutrition of a population is commonly defined by factors of food production, distribution, availability, consumption and utilization of nutrients. For the individual person, clinical history, clinico-nutritional examination, physical anthropometry, incidence of disease and injury, dietary studies, bone development and maturation, and biochemical tests are proved and useful procedures. Unfortunately, no generally accepted model exists by which nutritional state of the individual or of populations can be determined with quantitative exactness.

For the definition, classification and quantification of the independent variable, the following methodology is being used.

1. Clinico-nutritional examination: based on INCAP/ICNND (29, 30) and WHO (32, 43) data.

2. Neurology: methods of Richmond Paine (37), André Thomas (1) and Gesell (24).

3. Anthropometry: methodology used by the International Children's Centre (20) and Iowa (31) studies.

4. Morbidity: collected on house-to-house calls every 15 days.

5. Dietary surveys: INCAP's methodology using one or seven-day surveys (21, 30).

6. X-Rays: using the study methods of Greulich and Pyle (27), Tanner (42), cortical thickness of Fels Research Institute (22) and number of ossification centers (36).

7. Biochemistry: hemoglobin, hematocrit, total serum, protein and electrophoretic fractionation, albumin, globulin, A/G, serum, vitamin A and carotene, urinary excretion of creatinine, urea, urea/creatinine (2, 9, 14, 26, 28, 30, 36, 35).

Environment (Intermediate Variable)

The social impacts on mental development are many. Regardless of which socio-cultural variables are to have an eventual primary emphasis, it is mandatory to collect and study a wide range. Adequate characterization requires a detailed knowledge of the population under study with respect to family composition, child-rearing practices, social status, migration, patterns of communication, socialization processes, economic factors, family and community expectations, food habits, customs, beliefs, secular and introduced changes and perhaps others yet to be defined. An attempt has to be made to establish numerical relationships between selected ones and the nutritional state and mental development of populations and persons. That quantification is possible for all, or even the majority, is doubtful. Nevertheless, the effort is made although with practical conviction that numerous elements will have to be interpreted descriptively rather than in mathematical fashion.

Mental Development (Dependent Variable)

The tests developed to measure psychological development may be divided into two categories: a) developmental or infant scales, for use with infants from birth through two years of age; and b) a battery of tests for use with preschool children from three to seven years of age.

The infant scale is composed of items borrowed from the Bayley, Gesell, Cattell and Merrill-Palmer scales, and is used to measure development of children at three points during the first two years of life: 6, 15 and 24 months of age.

The choice of tests and test materials for the preschool battery, which is used from three to seven years, was guided by four primary considerations: a) the tests should be appropriate for the culture in which they are to be administered; b) the tests should require simple and, when possible, non-verbal responses; c) the tests should be "game-like", in order to maintain a high level of interest and involvement on the part of the subject; and d) the tests should tap what are generally considered fundamental cognitive processes.

The battery of preschool tests explores four areas of intellectual development: perception, learning, memory and language. In addition, several other tests are employed to investigate behavioral characteristics such as attention, motivation, persistence, resistance to distraction and ability to inhibit impulsive motor responses.

RESEARCH DESIGN

The main feature of the experimental design is an ecological approach by which two similar groups of children in rural Guatemala, one with an improved diet and the other with the conventional diet of the region, will be compared. The two child populations include all individuals aged less than seven years, along with newborn infants entering the group during observations lasting at least seven years. Ideally, the only difference between the two groups would be in nutritional status, a result impossible to achieve with human beings living in an open community.

The ideal experiment would cover the whole adaptive cycle from conception to adulthood. The most serious, and perhaps irreversible, physical and probably mental damage by malnutrition takes place during pregnancy and the first years of life. On the other hand, mental development is by no means so restricted, nor is early childhood necessarily the most critical time. Much of the learning process starts with the two-year old (6). Language learning occurs between two and twelve years of age. Memory is not fully developed until fourteen years. The complex process of a growing intelligence begins at four or five years and lasts until adult age. By current concepts, the critical age to study the effects of malnutrition is from six months until five years; the critical period to demonstrate its possible effects on mental development is from four years onward. Consequently, any study intended to demonstrate the significance of malnutrition as a factor in mental development must extend over sufficient time to permit proper definition and quantitative evaluation of both. A study limited to seven years faces the real possibility that the effects of PCM on mental development would not be fully determined. It should give, however, strong indication of the reasonableness of continuing observations. For many reasons, operational, administrative, technical and professional, the study is, at this point, limited to seven years. Providing results so warrant, the present research design has plans for an extension until children reach fourteen years.

The program focuses on the whole of physical and mental development, beginning with nutritional studies of the family unit and following pregnant women from conception through pregnancy and delivery. Newborns are observed from delivery to seven years of age, with periodic evaluation of nutritional status and mental development. The study is an interdisciplinary effort, specially involving integration of biological and socio-cultural variables. The programmed activities are presented on Table 1.

The final design includes three sets of communities, strictly matched for biological, psychological and socio-cultural variables. Population No. 1, defined as experimental, has nutritional supplementation and medical attention. In Population No. 2, the first control, medical attention is provided but no nutritional supplementation. Population No. 3 is called a blind control, it has neither element. In order to furnish the control community with the same or equivalent social stimulation as provided in the test population by the nutritional supplementation, a "fresco" (soft drink) without nutritional value is supplied.

Once a set of communities is found, the main variables introduced are: nutritional supplementation, medical care and social stimulation, the latter due mainly to the presence of the team in the village and to the interaction due to the nutritional supplementation provided in the experimental community. Thus, the final design is presented on Table 2. This type of design allows for isolation of the effects of nutrition and those of social stimulation on mental development.

Three sets of villages are under investigation. Each set per se is sufficient to provide the information required. The main reason to choose nine "aldeas" was to divide the risk of some unpredictable catastrophic event, such as an earthquake, volcanic eruption, drought, local political crisis, government intervention, intrusion of a new industry or the like, any of which could ruin a long-term prospective study. For concurrent replication of the experiment, for insurance if for no other reason, it is necessary to include the nine minimally required villages.

The criteria applied to match all villages include two groups of variables: quantifiable and non-quantifiable. The most important quantifiable variables are those which relate to physical growth, mental development and socio-cultural status. With respect to physical growth matching among preschool children, four anthropometric measures are applied: weight, height, arm circumference and tricipital skinfold thickness. For mental development matching, six measures covering the areas of attention, learning, memory and language are applied. The social quantifiable variables explored for matching are: size of population, size of sample, composition of the population, dependency rate, birth rate, mortality rate, financial status, land holding and use, housing, education, isolation and migration.

The non-quantifiable socio-cultural variables explored for community matching are: family composition, patterns of disease and injury, patterns of nourishment, expectation and social facilities.

RESULTS TO DATE

On the basis of the data collected during the exploratory phase of the study, some preliminary results are presented. These results illustrate the health conditions and mental performance of individuals living in the areas where the study is being carried out.

Diet of Pregnant Women

Table 3 summarizes the results of a dietary survey conducted in 58 pregnant women in two rural villages. A monthly dietary survey is obtained as soon as a pregnant woman is identified and continued until the time of delivery. Marked deficiencies can be noted during the three trimesters for practically all nutrients studied, being more severe during the first trimester. These deficiencies are more severe for calories, protein, vitamin A and riboflavin. Furthermore, the deficiency of protein is even more serious than indicated by total protein consumption, because only 20% of the total protein comes from animal sources.

Biochemical Analysis of Placentas

Table 4 shows the results obtained in 20 placentas belonging to rural women of two of the communities under study. The chemical composition of these placentas was found different from similarly processed placentas of women studied in the State of Iowa, U.S.A. (12). The average DNA concentration per kilo of placenta was 1.8 grams for the Guatemalan sample versus 3.42 grams for the North American sample. If it is assumed that the DNA concentration per cell is a constant factor, the total number of cells per placenta can be calculated. Accordingly, the total number of cells in placentas from the U.S.A. was calculated to be 2.517×10^{10}, and for the Guatemalan sample it was 1.697×10^{10}. In view of the severe dietary deficiencies occurring during pregnancy, it is reasonable to postulate that placental alterations could be partly due to these nutritional deficiencies. Furthermore, the anatomical changes could be responsible for functional alterations which, in turn, could damage the fetus. Further research is being carried out in this area.

Mortality in Preschool Children

Table 5 illustrates the patterns of death among children up to seven years of age in the villages under study. The death rates are higher during the neonatal period, and particularly high for the post-neonatal period and second year of life. The death rate in each community was taken into consideration to determine the sample size necessary to obtain a representative number of children at the end of the study. Based on this information and on the birth rates of the same communities, the size of the villages to be chosen for the study was also calculated.

Diet of Preschool Children

A recent and complete dietary survey of one of the communities is presented on Table 6. It can be seen that there is a marked deficiency for the majority of nutrients investigated. The deficiencies are more severe during the first two years of life. The nutrients showing the most severe deficits are similar to those obtained among pregnant women; that is, calories, protein, vitamin A, riboflavin, niacin and vitamin C.

Physical Growth

Graphs 1 and 5 present comparative values for height and weight between Guatemalan and U.S.A. preschool children. The Guatemalan sample includes 2800 children representing over 92% of this population group from eight rural communities. The standards of comparison for both measurements are the growth curves of Iowa (31).

The growth velocity in height is presented in Graph 2. It can be seen that during the first three months of life, the velocity is the same for both an urban healthy sample and a rural sample. After three months, however, there is a marked deceleration of growth velocity in rural children, lasting until about 30 months. Beyond 30 months they begin to recover, and by 60 months their velocity rate for height is practically the same as that of urban children.

Bone Development

Graph 3 shows cortical thickness as measured in the second metacarpal, in comparison with norms of the Fels Research Institute for a North American population; significant differences between the two samples are clear.

Graph 4 shows bone development studied by the Greulich and Pyle method, in a Guatemalan sample of 80 preschool children, representing practically 100% of the universe of one village.

Mental Performance in Malnutrition

A pilot study was conducted among 20 children who had been clinically diagnosed as malnourished at some point in early childhood, but who had been nutritionally rehabilitated at the time of testing. Height was also taken into consideration for the classification of malnutrition. The heights of the children in this sample were 14% or more below normal for their ages. The results obtained were compared with those of ten of their siblings, who had no clinical history of malnutrition, and whose height-for-age ratio showed a deficit between 0 and 10%. The results are expressed on Tables 7 and 8.

The control group performed significantly better than the experimental group in four of the ten measures used. Two of the tests which yielded significant group differences are adaptations of standard short-term memory tasks, Memory for Digits and Memory for Sentences. The other two tests which revealed significant group differences are Intentional and Incidental Learning. We are currently exploring three possible interpretations of these data: a) that children who have been malnourished are less competent in the area of short-term memory; b) that the group differences are due to an inability on the part of the previously malnourished children to respond verbally (ie, to decode experience linguistically); and c) that the previously malnourished subjects are unable to pay close attention during testing.

SUMMARY

Some illustrative points are presented showing that in the populations under study, there are marked nutritional deficiencies starting with pregnant women and early childhood. These deficiencies are reflected in placental alterations, poor and distorted physical growth and high mortality rates.

Children recovered from severe PCM performed less well in psychological tests than their siblings, pointing to the possibility that severe malnutrition within the same social environment can produce changes in mental development.

Long-term prospective studies are necessary to obtain data with which to demonstrate and quantitate the relative importance of the effects of socio-cultural and nutritional factors on mental development in developing countries.

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TABLE 1

PROGRAM ACTIVITIES OF THE GROWTH AND DEVELOPMENT UNIT

	PREGNANCY									N.B.	1 YEAR						2 YEARS				3 YEARS				4 YEARS		5 YEARS		6 YEARS		7 YEARS	
MONTHS	-1	-2	-3	-4	-5	-6	-7	-8	-9	0	2	4	6	8	10	12	15	18	21	24	27	30	33	36	42	48	54	60	66	72	78	84
Pre-natal Nurse	x	x	x	x	x x	x	x	x	x x x x	x																						
Pre-natal M.D.				x				x		x																						
Placental Study										x																						
Anthropometry Neurology										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Clinico-Nutritional										x			x			x		x		x		x		x	x	x	x	x	x	x	x	x
X-Rays													x			x		x		x		x		x	x	x	x	x	x	x	x	x
Biochemistry*			x					x		x			x			x		x		x		x		x	x	x	x	x	x	x	x	x
Dietary Survey Pregnancy	x	x	x	x	x	x	x	x	x																							
Dietary Survey Pre-school child																x	x	x	x	x	x	x		x		x	x	x	x	x	x	x
Milk Production**											xx	xx	xx	xx	xx	xx	xx															
Psychology													x				x			x				x		x		x		x		x

* Urine samples would be obtained whenever possible from each child, pregnant woman and lactating mother during each visit.

** The quantity of breast milk produced is studied in cohorts of 5 mothers.

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TABLE 2

	EXPERIMENTAL	CONTROL 1	CONTROL 2
MEDICAL CARE	X	X	O
NUTRITIONAL SUPPLEMENTATION	X	O	O
SOCIAL STIMULATION - "fresco"	O	X	O

TABLE 3

DIETARY INTAKE AMONG PREGNANT AND LACTATING WOMEN

LOS PLANES 1968

		CALORIES		TOTAL PROTEIN (gm)		ANIMAL PROTEIN (gm)	CALCIUM (mg)		NIACINE (mg)		RIBOFLAVINE (mg)		IRON (mg)		THIAMINE (mg)		VITAMIN A (mg)		VITAMIN C (mg)	
Trimester	N	Total Amt.	%	Total Amt.	%	Total Amt.	Total Amt.	%	Total Amt	%	Total Amt.	%	Total Amt.	%	Total Amt.	%	Total Amt.	%	Total Amt.	%
1	20	1418	71*	39.2	65*	8.0	768	171*	7.0	53*	0.68	57*	16.9	169*	0.81	101*	0.47	36*	36.5	81*
2	57	1723	78*	49.7	71*	7.4	967	88*	9.7	67*	0.71	55*	16.9	121*	0.99	110*	0.53	33*	28.8	44*
3	57	1819	83*	53.9	77*	8.7	1012	92*	10.3	71*	0.79	61*	20.3	145*	1.07	119*	0.75	47*	39.4	61*
Lactating	36	1599	57*	58.0	68*	9.9	887	81*	9.9	54*	0.58	34*	21.3	152*	1.03	94*	0.34	16*	12.9	14*

* INCAP Daily Nutritional Recommendations for Populations of Central America and Panama. Revised June, 1965

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TABLE 4

PLACENTAL COMPOSITION

U. S. A. (20) vs. GUATEMALA (20)

	$\bar{x}$	SD	"t"	Significance
WEIGHT (gm)				
U. S.	414.3	113.0		
GUATEMALA	435.5	136.3	-0.464	.6 p .7
DNA (gm)**				
U. S.	3.989	0.785		
GUATEMALA	1.850	0.654	5.584	p .002
No. OF CELLS ($\times 10^{10}$)**				
U. S.	2.517	0.628		
GUATEMALA	1.697	0.384	4.670	p .002
CONCENTRATION PER CELL (uug.)*				
N/CELL ($\times 10^{-1}$)				
U. S.	3.710	0.878		
GUATEMALA	4.313	1.177	-1.578	.1 p.2
Fe/CELL ($\times 10^{-3}$)				
U. S.	2.346	0.766		
GUATEMALA	1.991	1.109	1.008	.3 p.4
CU/CELL ($\times 10^{-5}$)				
U. S.	5.375	2.534		
GUATEMALA	5.752	2.413	-0.430	.6 p .7
Zn/CELL ($\times 10^{-4}$)**				
U. S.	1.134	0.759		
GUATEMALA	2.138	0.692	-3.922	p .002
Mn/CELL ($\times 10^{-6}$)				
U. S.	4.722	1.638		
GUATEMALA	3.872	2.874	0.967	.3 p .4
Cr/CELL ($\times 10^{-6}$)**				
U. S.	6.015	3.018		
GUATEMALA	3.036	1.879	3.506	p .002

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* Assuming constant DNA per cell

** Significantly different

TABLE 5

DEATH RATES AMONG PRESCHOOL CHILDREN IN A RURAL GUATEMALAN VILLAGE

Age groups	Death Rates per 1,000 children	
	Acatenango 1960-1965	Rural Guatemala* 1959-1964
Peri-Natal	59	30 +
Neo-Natal	65	64.4
Post-Neonatal	48	83.4
Second Year	45	51.7
Third Year	24	32.8
Fourth Year	13	20.1
Fifth Year	10	12.5
Sixth Year	3	-

* INCAP-OIR

\+ Death 0-6 days

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TABLE 6

AVERAGE INTAKE LEVELS OF NUTRIENTS IN PRESCHOOLERS
LOS PLANES - 1968

Age (yrs)	N	Calories		Protein (gm)		Calcium (mg)		Iron (mg)		Vit. A (mg)		Thiamine (mg)		Riboflavine (mg)		Niacin (mg)		Vit. C (mg)	
		Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%
1	8	579	45	15.9	49	392	49	5.4	68	0.281	47	0.37	74	0.53	66	2.71	30	17	42
2	9	807	62	21.2	66	423	53	7.2	90	0.222	37	0.42	84	0.27	34	4.74	53	14	35
3	10	1139	71	30.6	76	527	66	12.5	125	0.317	42	0.61	102	0.36	36	5.66	51	16	32
4	15	1219	76	32.7	82	673	84	13.7	137	0.380	51	0.76	127	0.43	43	6.51	59	21	42
5	2	1498	94	37.3	93	850	106	18.0	180	0.313	42	0.92	153	0.44	44	8.28	75	24	48

* National Research Council Recommended Allowances, 6th revised edition, 1964.
A report of the Food and Nutrition Board, NAS/NRC, Publication 1146.

TABLE 7

DESCRIPTIVE DATA - EXPERIMENTAL AND CONTROL GROUPS

GROUPS	AGE/MONTHS	HEIGHT/CMS.	% DEFICIT HEIGHT/AGE
CONTROL GROUP N = 10	$\overline{X}$ = 67.60 SD = 8.15 R = 55-77	$\overline{X}$ = 106.85 SD = 5.40 R = 95-115	$\overline{X}$ = 7.10 SD = 2.38 R = 5-10
EXPERIMENTAL GROUP N = 20	$\overline{X}$ = 64.40 SD = 7.20 R = 54-78	$\overline{X}$ = 95.56 SD = 4.34 R = 88.9-102	$\overline{X}$ = 15.50 SD = 3.83 R = 13-28

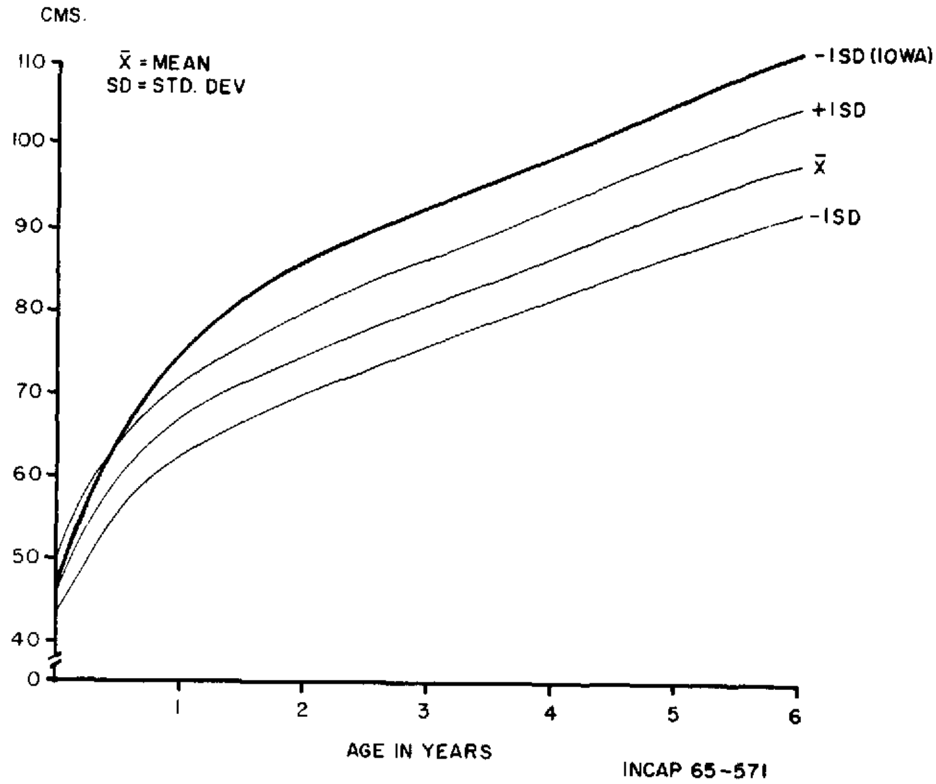
TABLE 8

MEANS, STANDARD DEVIATIONS AND RANGES FOR EXPERIMENTAL AND CONTROL GROUPS AND TESTS OF SIGNIFICANCE OF GROUP DIFFERENCES

T E S T S	CONTROL	EXPERIMENTAL	VALUES OF U, T AND SIGNIFICANCE LEVELS
MEMORY FOR DIGITS	$\bar{x}$ = 47.50 SD = 6.86 R = 42-60	$\bar{x}$ = 32.75 SD = 12.92 R = 15-63	T = 3.36 (df=28) $P < .01$
MEMORY FOR SENTENCES	$\bar{x}$ = 65.20 SD = 12.53 R = 50-94	$\bar{x}$ = 48.55 SD = 22.34 R = 5-78	T = 2.18 (df=28) $P < .05$
INCIDENTAL LEARNING	$\bar{x}$ = 1.70 SD = .95 R = 0-3	$\bar{x}$ = 0.80 SD = 1 R = 0-3	U = 48 (n_1=10, n_2=20) $P < .05$
INTENTIONAL LEARNING	$\bar{x}$ = 3.10 SD = 1.30 R = 1-5	$\bar{x}$ = 1.90 SD = 1.50 R = 0-4	U = 54 (n_1=10, n_2=20) $P < .05$

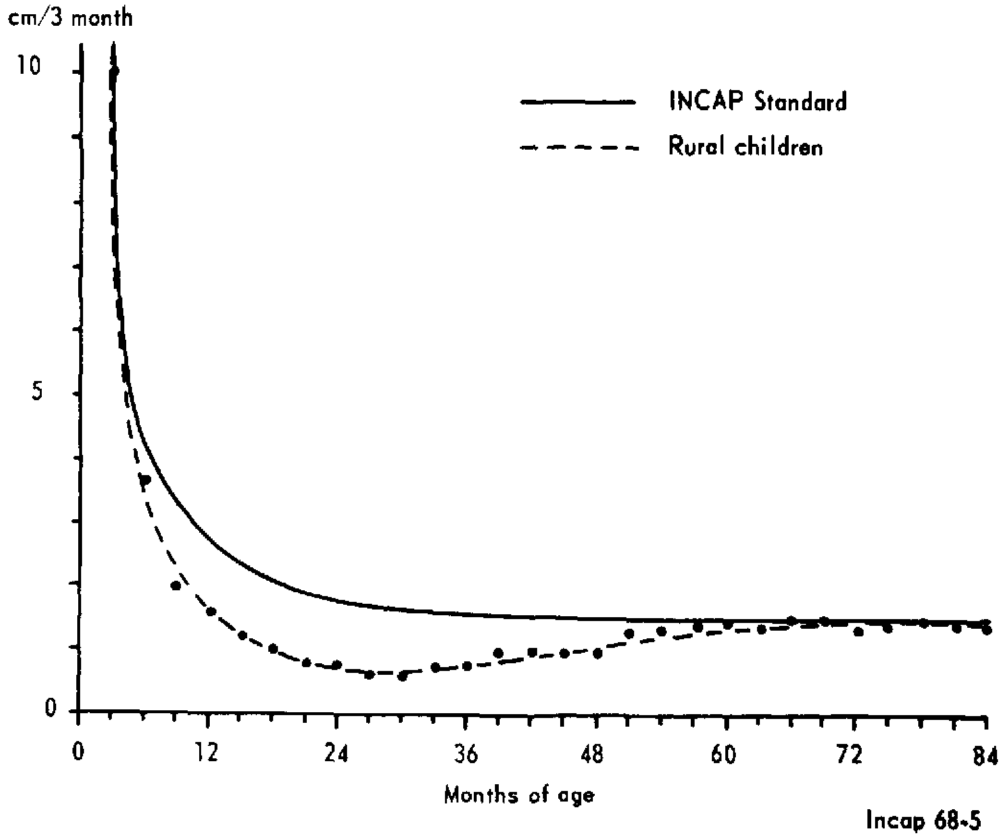
GRAPH 1

HEIGHT FOR PRE-SCHOOL BOYS IN 8 RURAL GUATEMALAN VILLAGES 1965

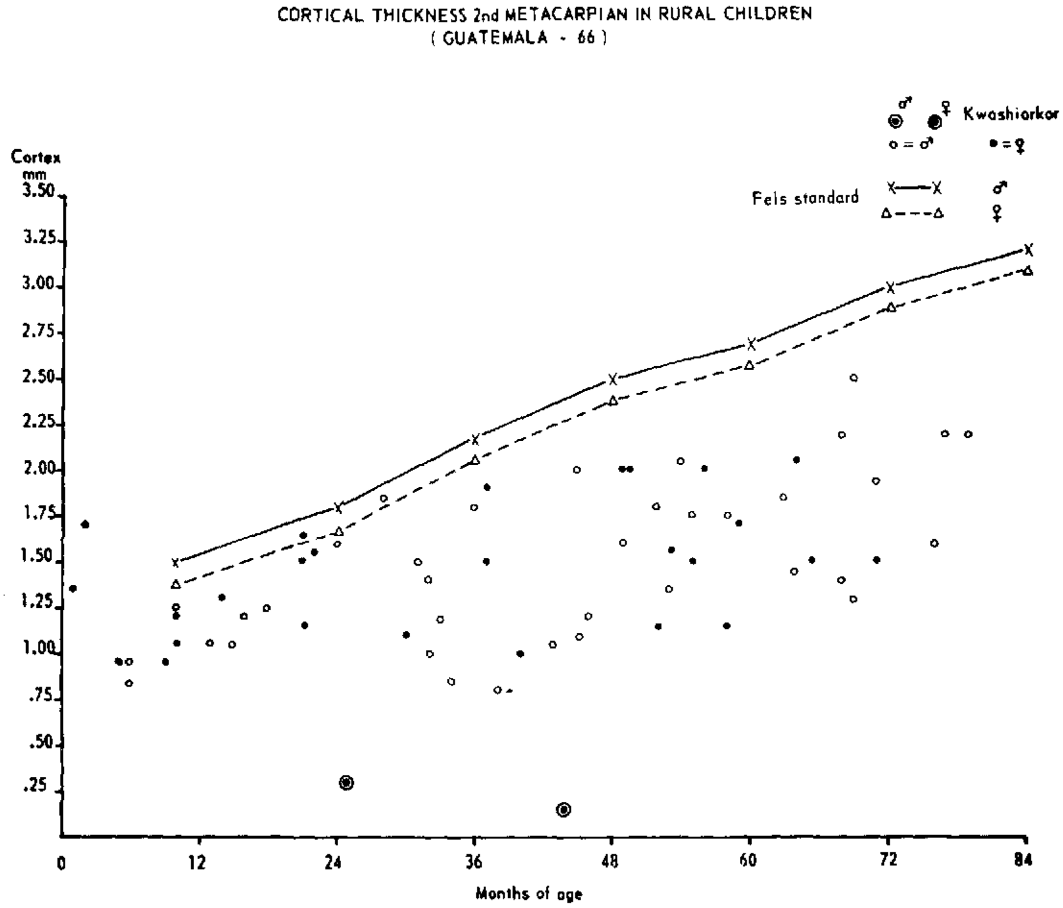


GRAPH 2

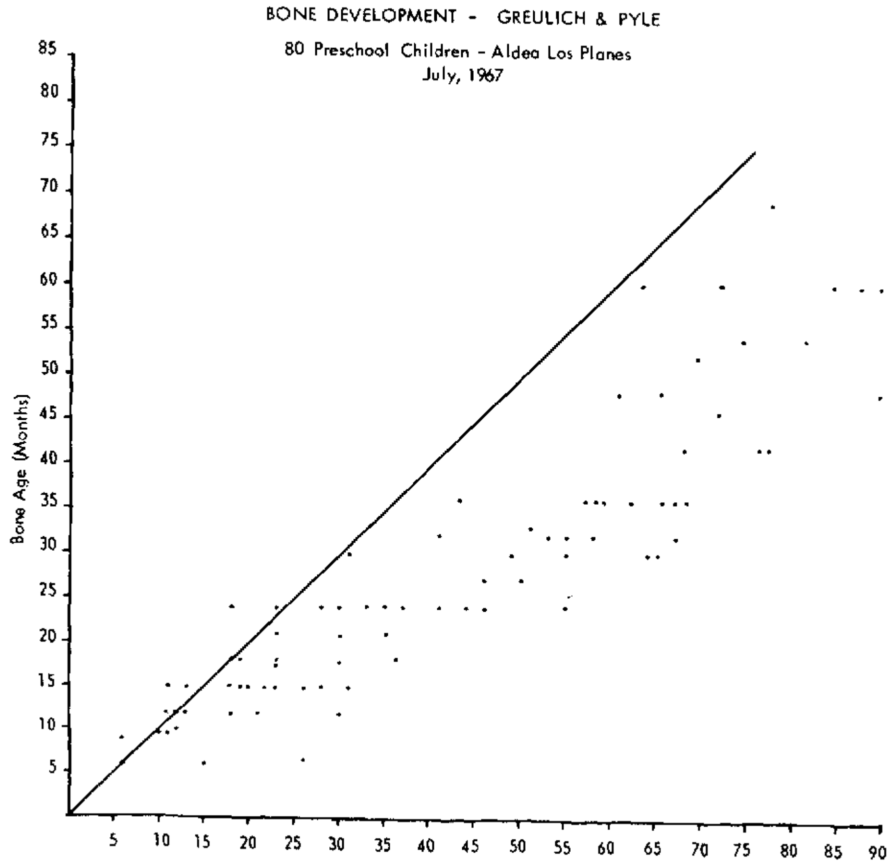
QUARTERLY INCREMENTS OF GROWTH IN HEIGHT FOR RURAL CHILDREN GUATEMALA 1968



GRAPH 3

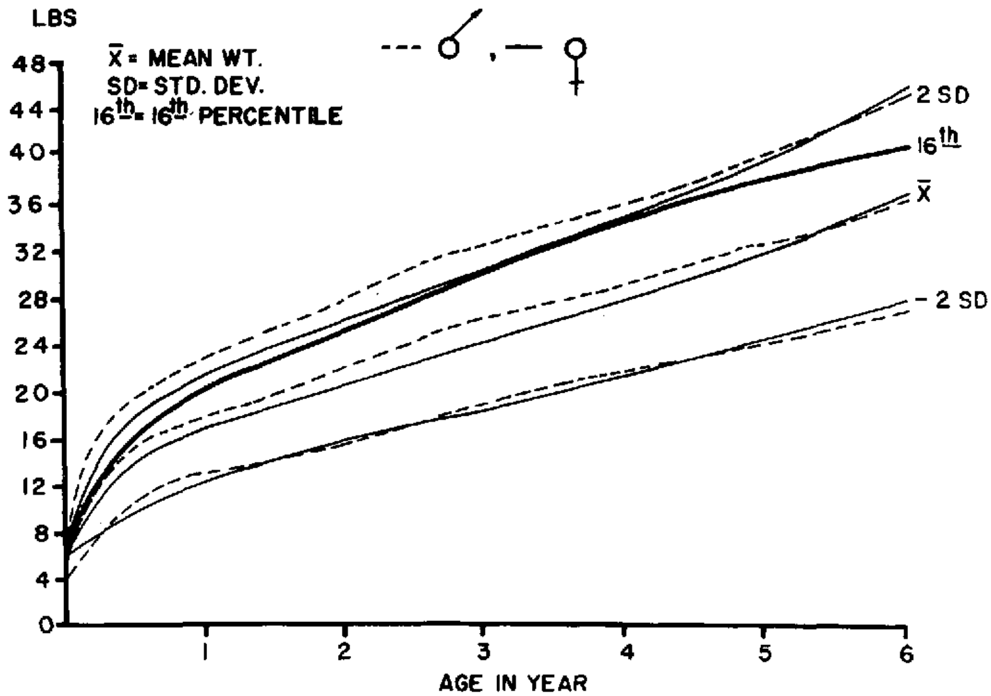


GRAPH 4



GRAPH 5

WEIGHTS OF PRE-SCHOOL BOYS AND GIRLS IN 8 RURAL GUATEMALAN VILLAGES 1965



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