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Timing of Neurological Development in Rural Guatemalan Children

Delbert H. Dayton, M.D., and Ricardo A. Blanco, M.D., M.P.H.

From the National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, Maryland, and the Institute of Nutrition of Central America and Panama (INCAP), Guatemala

ABSTRACT: This is a cross-sectional study of the anthropometric measurements and neurological evaluation of 559 children under 36 months of age (286 boys and 273 girls) from a rural area of Guatemala. Height and weight were compared with values from well-nourished Central American children which do not differ from North American standards. Head circumference was compared to standards from 14 different studies compiled from the world literature. The analysis of the data showed that the study population was far behind these standards in its physical growth characteristics. Results are presented for the timing of neuromotor skill development by calculation of the 16th, 50th and 84th percentiles for individual neurological functions by the probit method. Comparable data from other populations using the probit method of analysis are generally not available. One exception is the age of walking, which appeared to be delayed approximately four months in the rural Guatemalan children when compared to previous studies analyzed in this manner. These results should not be taken as patterns or norms but rather as a baseline for future studies. *Pediatrics*, 53:726, 1974, NUTRITION, ENVIRONMENT, NEUROLORY, GROWTH, DEVELOPMENT.

In the general sense neurological development applies to the process of change which takes place in the structure and function of the central nervous system (CNS) between immaturity and complete maturity..

When the child's life begins with fertilization of the ovum, his prenatal development is regulated by a continuous interaction of genes with their surrounding cytoplasm. This continuous process is a chain of complicated physiochemical reactions, which may be interrupted or diverted by genetic or environmental factors.[1]

The velocity of growth and maturation is genetically predetermined in each individual,[2-7] and there is overwhelming evidence that physical growth characteristics are environmentally influenced.[8-17]

Although in animals, studies of malnutrition and its effects on brain function have been described in detail,[18-20] in humans there are only reports of the effects of kwashiorkor on the EEG tracings,[21,22] mental changes and neurological manifestations,[23-25] or psychological changes related to malnutrition.[26-32] No known previous effort has been made in studies of malnourished children to develop an instrument or train a team of examiners to evaluate neurological development in young children using this approach to assessment with adequate validity and reliability.

The present study is concerned with the *timing* of development of neurological skills in a sample of malnourished children from the rural area of Guatemala.

MATERIAL AND METHODS

Under the hypothesis that malnutrition produces not only physical impairment but also permanent impairment of mental function, the Division of Human Development at the Institute of Nutrition of Central America and Panama (INCAP) developed an experimental design for a longitudinal study to be performed in a Guatemalan rural area, where malnutrition is prevalent. This smaller cross-sectional study is a part of that effort.

After a careful study of the characteristics of

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ADDRESS FOR REPRINTS: (D. H. D.) Growth and Development Branch, National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, Maryland 20014.

approximately 30 villages of rural Guatemala, five of them were chosen as being homogeneous in demographic and economic variables, and were classified as poor, rural, and predominantly Ladino* villages, and all were located within a 60-mile radius of INCAP headquarters. This study was performed in those five villages.

The sample consisted of 559 children aged 0 to 36 months. Of those, 286 were boys (51.2%) and 273 girls (48.8%). Fifty-eight children were classified as Indians, the rest were classified as Ladinos. The age given by the parents was confirmed in the local Civil Register and those children who did not have accurate information were excluded from the study. Also excluded from the study were those children who, at the moment of the examination, presented some kind of acute or chronic disease other than malnutrition. No child was included more than once in the sample.

The nutritional status of the population from whom the sample was taken has been described by other investigators,[15,33,34] and the incidence of infectious diseases has also been described by several authors.[35-38]

The data were collected by the senior author who spent two months training personnel and standardizing procedures in a nursery located in the city of Guatemala, prior to collecting the data.

At the time of the examination, all efforts were made to make the child feel comfortable and be without fear. The presence of the child's mother or siblings was permitted in the room to make him feel secure and put him at ease. Short play periods preceded the testing.

Anthropometric Measurements

(1) *Weight* was measured with a Toledo Scale with a sensitivity of ±20 gm. The child wore clothes, supplied for the examination, of known weight which was subtracted from the total to obtain the child's true weight; this measurement was recorded in kilograms. (2) *Height* was taken in centimeters, with the child lying down and without shoes using a Harpenden Infant Measuring Table graduated in centimeters and millimeters. (3) *Head circumference* was taken in centimeters, with a metal tape that was placed at the supraorbital region or at the level of both frontal protuberances. Posteriorly it was placed at the external occipital protuberance. The maximum diameter was obtained in this manner.

Neurological Examination

Almost all the information on the neurological functions was obtained by direct observation of the child's performance. The examiner spent more than two hours with each child and in that time was able to evaluate the child's ability in language and neurological functions. Information on control of sphincters was obtained from the mother.

TABLE I

DISTRIBUTION BY AGE, SEX AND RACE OF 559 PRESCHOOL RURAL GUATEMALAN CHILDREN

Age in Months	*Boys*			*Girls*			*Grand Total*
	Ladino	*Indian*	*Total*	*Ladino*	*Indian*	*Total*	
0– 6	61	7	68	62	9	71	139
7–12	58	5	63	65	0	65	128
13–18	51	9	60	49	3	52	112
19–24	47	9	56	52	5	57	113
25–30	16	5	21	14	1	15	36
31–36	15	3	18	11	2	13	31
Total	248	38	286	253	20	273	559

In addition to the neurological assessment presented in this paper, each child was tested for the following deep tendon reflexes; biceps, triceps, radial, patellar, and achilles. The abdominal superficial reflex and Babinski were also evaluated as well as response to pin prick and vibration, facial symmetry, reaction of eyes to light and accommodation, extra-ocular muscle testing, size and equality of pupils, ciliary and blink reflexes and examination of ocular fundi and cranial nerve testing as age and observation would permit. In our selected sample, no abnormalities were encountered through this assessment. It should be stated that grossly abnormal children had previously been eliminated from the sample through knowledge of past medical histories and observations of individual children.

The following additional neurological assessment items were used in the testing and were obtained from the writings of previous investigators.[39-42]

1. *Vertical Suspension.* The child is suspended vertically with the observer's hand under his axillae: (a) *controls head:* the child shows ability to maintain head erect in vertical position; also he is able to resist a push against forehead; (b) *flexes arms:* if the child keeps his arms predominantly in flexed position; (c) *flexes legs:* if the child keeps his legs predominantly in flexed position.

2. *Horizontal Suspension.* The child is suspended with the examiner's hand placed between chest and stomach; position of head and position of legs are noted: (a) *flexes head:* the head is held flexed in relation to the major axis of the body; (b) *head in line with body:* the child keeps his head level

* A Ladino is a native Guatemalan who has adopted Spanish cultural practices. Genetically he is a mixture of Indian and Spanish, the Spanish ancestry being predominant.

with the major axis of the body; (c) *head in hyperextension*: the child keeps his head at a level above the major axis of the body; (d) *extension of legs:* the child's lower limbs are unbent at the knees and hips and placed at a level below the major axis of the body; (e) *hyperextension of legs:* the lower limbs are extended in such a manner that the knees and hips are above the major axis of the body.

3. *Social.* (a) *Fixates on mother when spoken to:* a positive response is recorded when the child fixes his attention on his mother or another person when spoken to, as direct response to this social stimulation; (b) *social smile:* must result from interaction between the child and another person; no credit is given if the smile is spontaneous, without a reaction to a direct social stimulus; (c) *social laugh:* the child responds to a social stimulus with abdominal-type laugh and at the same time has a pleased expression; the mother's testimony that the child socially laughs with her is accepted.

4. *Auditory Response.* (a) *Facial response to auditory stimulus:* an object emitting a sound of uniform frequency and intensity (bell) is used; increase in palpebral opening, gestures, smiles, or lowering of general activity were taken as a positive response; (b) *turns the head to auditory stimulus:* using the same stimulus as above the examiner observes whether or not the child turns his head toward the side where stimulation was produced; the child is not given visual cues in performing this task, e.g., examiner's movements.

5. *Visually Follows Four-Inch Red Ball Horizontally.* A bright red ball four inches in diameter is used, suspended from a rubber cord. Two responses are recorded: (a) *follows 30 degrees with ease (more than 50% of the time):* the child is capable of following with his eyes up to 30 degrees more than 50% of the time; degrees are measured in relation to the anteroposterior plane of the head and horizontal ocular movements evaluated; (b) *follows 90 degrees with movement of the head:* the child is capable of coordinated eye and head movement and can follow the object horizontally up to 90 degrees using head and eyes.

6. *Visually Follows Four-Inch Red Ball Vertically.* Exploration is continued with the same ball. Three responses are recorded; (a) *follows less than 30 degrees:* the child moves his eyes vertically very slightly and less than 30 degrees; (b) *more than 30 degrees:* when he moves his eyes more than 30 degrees but without head movements; (c) *more than 30 degrees with head movements:* (self-explanatory).

7. *Grasps Dangling Object (Four-Inch Red Ring).* Three responses are recorded with child in supine position: (a) *movement of arms:* credit is given if the child shows arm movements in response to the stimulus; (b) *opens and closes fingers at a distance:* the examiner observes whether or not the child extends and moves his fingers as though trying to grasp the ring; (c) *grasps dangling object:* if the child reaches the object and grasps it.

8. *In Prone Position Approaches and Takes Object.* (a) *with both hands:* if the child reaches the object with both hands; (b) *if he does it with one hand;* (c) *fixates on object:* the bright red ball is placed within the child's line of vision; the examiner observes whether or not the child looks steadily at it; (d) *facial response to visual stimulus:* credit is given if changes in facial expression and increase in palpebral opening are observed when the red ball is presented; (e) *fixes vision on his hands:* the ability to look at his own hands, even for a moment, is explored; (f) *puts hand in contact in midline:* the fingers of both hands come together, touch and explore each other; (g) *removes handkerchief from face:* the child's face is covered with a handkerchief and his hands are left free (self-explanatory); (h) *manipulates object with purpose:* the child is given a simulated rattle (cylindrical piece of wood measuring 12 × 7 cm, the end of which is rounded and painted red); the movements of arm and hand to facilitate looking at the object are observed; (i) *transfers object from one hand to the other:* using the same stimulus as above, the examiner observes whether or not the child transfers the object from one hand to the other; (j) *releases objects voluntarily:* observation with the foregoing item; the examiner observes whether or not the child performs this act voluntarily upon command; (k) *correlates hand opening with size of the object:* a 2-inch red cube is used and the way in which hand is shaped in preparation for grasping is observed. Credit is given when the opening of the hand is proportionate to the size of the object.

9. *Prone Position.* The child is placed on his stomach with his nose against the mattress or examination table. The following reactions are ob-

TABLE II

MEANS AND PAIRED T TESTS FOR WEIGHT, HEIGHT, AND HEAD CIRCUMFERENCE BETWEEN THE LADINO GROUP AND THE INDIAN GROUP IN RURAL GUATEMALAN CHILDREN

	Ladinos Mean	*Indians Mean*	*No. Pairs*	*t*	*p*
Weight*	7.14	7.05	54	0.472	>0.05
Height†	66.75	66.30	54	0.653	>0.05
Head Circumference†	42.60	42.70	54	0.337	>0.05

* Weight in kilograms.

† Height and head circumference in centimeters.

served: (a) *raises head, frees nose and chin:* the child lifts his head slightly above the surface of the table, but it drops immediately; (b) *raises head less than 45 degrees:* when the child keeps head erect and extended but forms an angle of less than 45 degrees in relation to the horizontal plane of table, for more than 15 seconds; (c) *raises head more than 45 degrees:* same criteria but this time the head forms an angle of more than 45 degrees with horizontal; (d) *supports self on forearms:* if the child is able to lift head and upper part of trunk by supporting his weight on his forearms; (e) *supports self on hands:* if the child lifts his head and chest from the surface on which he is lying and supports his weight on his hands (upper limbs extended during this maneuver); (f) *rolls over from prone position:* the child is able to turn without help from abdomen to back; (g) *rolls over from supine position:* the child is able to turn without help from back to abdomen; (h) *kneels:* the child is made to lie on his chest on the table; the observer notes whether or not the child can assume a kneeling position on his own; (i) *creeps (hands and knees):* the child is able to move on hands and knees keeping stomach raised from the surface of the table.

10. *Traction Response.* The child is pulled by his hands to sitting position. The following responses are noted: (a) *head lag without participation:* the child's head falls back and he makes no effort with his arms to participate actively in the movement; (b) *no head lag without participation:* there is no head lag but head is held in a straight line with the major axis of the body, and the child makes no effort to participate with his arms; (c) *no head lag with participation:* same as (b) but the child makes an effort with his arms to participate actively in the movement.

11. *Sitting.* (a) *Sits supported by arms:* the child maintains sitting position with passively flexed trunk and propped up with his arms as support; (b) *sits alone:* the child maintains sitting position for more than 60 seconds without support.

12. *In Sitting Position Without Falling.* (a) *Follows 4-inch red ball on a cord horizontally:* the child is able to follow a red ball when moved horizontally, while in unsupported sitting position; (b) *follows 4-inch red ball vertically:* follows the same ball vertically while in unsupported sitting position; (c) *sustains unsupported sitting position following a lateral push from physician without overbalancing:* (self-explanatory); (d) *sustains unsupported sitting position following posterior push without overbalancing:* (self-explanatory).

13. *Standing.* (a) *Primary neonatal type standing:* ability in the newborn to right himself when his feet are placed on the table; he maintains erect

TABLE III

CORRELATIONS FOR HEIGHT, WEIGHT, AND HEAD CIRCUMFERENCE, BY SEX, FOR RURAL GUATEMALAN CHILDREN

	Boys	*Girls*
Age–height	0.882	0.902
Age–weight	0.786	0.820
Height–weight	0.948	0.940
Age–head circumference	0.736	0.806
Height–head circumference	0.878	0.915
Weight–head circumference	0.868	0.897

position with legs somewhat rigid but knees do not extend and he sustains little weight on lower extremities; (b) *physiological astasia:* the child loses ability to right himself with disorientation of feet when placed on the table and passive flexion of trunk on the thighs; (c) *definitive standing:* when erect position is sustained, progressively becoming firmer; body weight rests on the sole of the feet and toes are extended.

14. *Locomotion.* (a) *Neonatal walking reflex:* the trunk is supported and inclined forward, thus allowing the newborn to make reflex movements in an attempt to walk; (b) *abasia:* when the maneuver described above is performed, the feet drag and are placed inadequately, having lost neonatal walking reflex; (c) *definitive walk:* if he is pushed forward steadily, he attempts to walk once again; at first his steps may show neither rhythm nor coordination; movements at first are abrupt and frequently isolated; (d) *walks holding rail:* credit is given when the child, in a playpen, is capable of walking around by holding on to the railing; credit is also given if he can walk holding on to his mother, furniture or other objects; (e) *walks with one hand held:* if the child can walk holding on to mother's hand or to that of another person; (f) *maintains balanced stance:* when the child has the ability to stand without support for at least 60 seconds; (g) *from unsupported standing position sits down on floor unaided:* (self-explanatory); (h) *walks without support:* the child can walk with acceptable balance and is capable of taking a few steps without falling; no credit is given when the child is able to perform three or four crude forward steps into his mother's arms or the arms of another person; (i) *walks with flexion of knees and hips:* credit is given when coordinated walk begins to show characteristics of flexion of hips as well as knees; (j) *walks with heel touching floor before the plantar surface:* in walking heel touches floor first so that the typical heel-toe walk is present; (k) runs well: the more rapid and exact synchronization of the walking movements, with the child moving swiftly without falling.

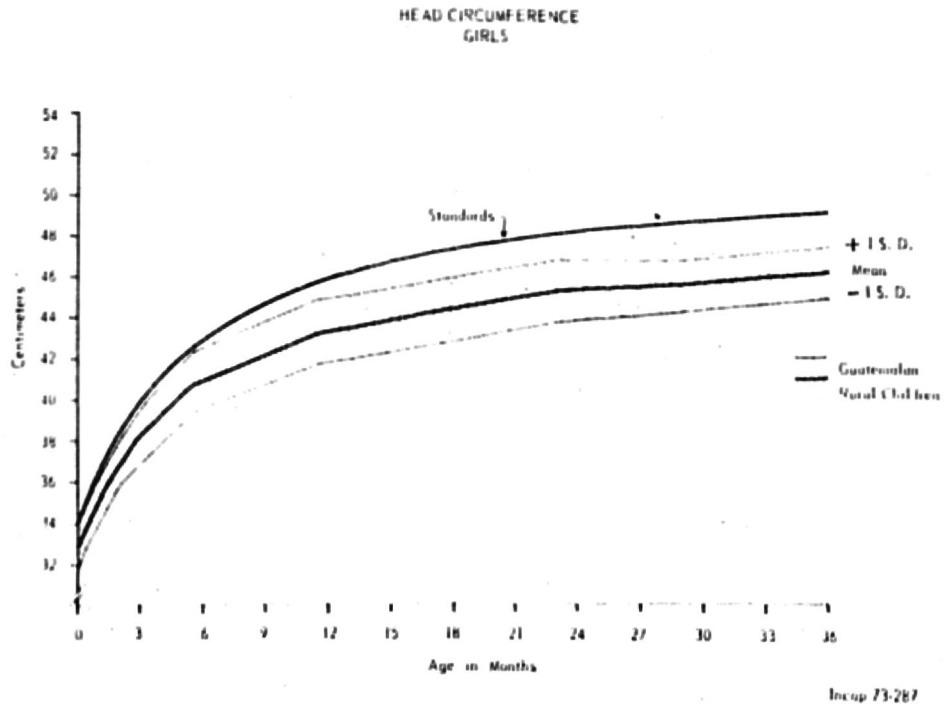

FIG. 1. Mean ±1 standard deviation for height, weight and head circumference by age and sex for Guatemalan children. Height and weight are compared with means for well-nourished Central American children. Head circumference is compared with standards prepared by Nellhaus.

15. *Pellet Testing.* A pink pellet is placed on a table with a dark top, at a distance of 16 cm from the child. The child is sitting on his mother's lap, with arms on the table. The following reactions are noted: (a) *regards pellet:* if the child only looks at the pellet without other activity; (b) *rakes with hands:* clumsy movements of the palm of the hand; the thumb remains inactive; (c) *rakes with radial border:* the movements are still clumsy; the child tries to grasp the pellet with the first three digits: thumb, index and middle fingers; (d) *scissors grasp:* a more refined type of prehension than those described above; it is characterized by the extended position of the thumb and the index finger, which makes for more efficient object prehension; when the child tries to grasp the pellet, the edges of thumb and index fingertips are brought together; (e) *inferior pincer grasp:* prehension is accomplished by means of a pincer using the anterior part of the tip of thumb and the extended index finger; during this maneuver, the hand and forearm form a straight line; (f) *fine pincer:* the thumb and index finger are used to approach the pellet, the hand rotated internally at the wrist. The angle formed by the thumb and index finger is similar to the one formed by an adult's hand.

16. *Language.* The examiner listens carefully before, during and after the examinations for the different types of sounds uttered by the child; he also is aware of the circumstances under which the child makes these sounds. Data also can be obtained from the mother or from the person in closest contact with the child. The following are recorded: (a) *vocalizes in reply to social stimulation:* credit is given if the child is able to vocalize some squeals of contentment when socially stimulated; (b) *recognizes his name:* when the child gives clear signs of having recognized his own name when addressed by it; (c) *meaningfully uses "mama"-"papa":* when the child uses the word "mama" or a substitute word for his mother or for the mother figure and does not apply that word to any other person; the same criterion for the word "papa"; (d) *responds to "no":* the examiner tells the child firmly, "no, no" in inhibiting an exploratory situation set up for the child; credit is given if the child is inhibited in his activity, even partially, when he hears the order; (e) *pat-a-cakes:* (self-explanatory); (f) *waves "bye-bye":* if the child is able to indicate "goodbye" either with the gesture or with words plus the gesture; (g) *understands "Give it to me":* the examiner close to the child looks at him and extends his hand as though begging, and says, "Give it to me"; if the child does not respond by offering the 2-inch red cube he repeats the instruction; if he does not respond to the examiner the mother is allowed to give the command bringing her hand near to the child in a begging attitude; the words are pronounced gently; credit is given if the child makes a giving gesture and releases the object into the examiner's hand or into his mother's hand; (h) *says two or three words:* credit is given when the child uses two or three words meaningfully even though they may be abbreviated or distorted; (i) *short sentences:* when the child uses short three-word sentences; (j) *sentences:* credit is given when the child pronounces more than four words with a definite meaning and vocalizes using well-formed simple sentences containing innumerable words.

17. *Achieves Bladder Sphincter Control.* (a) *Daytime:* when the child is conscious of the act of urination and controls his sphincter while awake; information provided by the mother is accepted; (b) *nighttime:* the same definition as above.

18. *Achieves Rectal Sphincter Control.* (a) *Daytime:* when the child attains daytime voluntary control over act of defecation; (b) *nighttime:* the same definition as above, information provided by the mother is accepted.

19. *Responses and Reflexes.* (a) *Palmar grasp:* credit is given if slight pressure on the metacarpophalangeal groove produces involuntary flexion of the fingers. The thumb follows the movement of the fingers, flexing if it was originally in passive extended position; (b) *plantar grasp:* credit is given if pressure on the metatarsophalangeal groove of the sole produces a strong involuntary flexion of toes, as though to grasp an object; credit is given also if the strength of toe flexion movement does not reach the point where an object can be grasped; (c) *sucking reflex:* when mouth or tongue

is stimulated with a finger or rubber nipple, the child begins sucking movements; (d) *rooting reflex:* credit is given when the child opens mouth and follows to the right or left, up or down, when his mouth is stimulated in any of these directions; (e) *crossed extension:* (1) *flexion, adduction and extension:* the examiner applies moderately strong pressure against the sole of one of the child's feet; credit is given when flexion and adduction are produced, followed by extension of the opposite limb as though the child wants to push away the person performing the maneuver; (2) *cortical response:* when the movement of the limb opposite to the one stimulated is voluntary; (f) *tonic neck reflex:* in supine position, the child's head is turned to one side or, if turned spontaneously, positive response consists of a degree of extension of the upper and lower limbs on the side to which his face is turned, with the opposing upper and lower limbs flexed; (g) *Moro's reflex (by hyperextension of head):* with the child in supine position, the examiner raises his head slightly and then releases it and the response is descriptively recorded (arms extended, fingers extended and arms abducted); (h) *Moro's reflex (by extending hands and releasing):* the child is in supine position, and by grasping both the child's hands, the examiner attempts to draw the trunk up from the surface of the examination table and then releases the child's hands abruptly. The various combinations of responses of arms extended, fingers extended or arms abducted are recorded; (i) *cochleopalpebral:* reaction to a sharp noise is noted; this reaction consists of bilateral and spontaneous closing of eyes; the noise is produced by impact of two circular wooden plates 11 cm in diameter; (j) *withdrawal reflex:* obtained by stimulating the surface of the sole of foot with a stylet; this produces an involuntary withdrawal response of the foot and entire leg; withdrawal of the foot is sufficient to give credit; (k) *parachute response (precipitation):* the child is held in suspension by the trunk and plunged, head down, towards a flat surface, thus causing projection of arms with hands and fingers extended as though trying to protect himself from the fall; three reactions are observed: (1) *contact on palms:* the child makes contact with palmar surfaces of hands with fingers extended; (2) *supports body's weight:* supports body weight on hands and arms; and (3) *hyperextension of the neck:* it is noted if his neck is in hyperextended position at the time of the maneuver as seen in older babies; (l) *trunk elevation response (redressement du tronc):* the child is suspended horizontally, doubled at the waist, with his buttocks against the examiner's chest; pressure is applied to the soles of the feet, causing dorsiflexion movements of trunk followed by raising of the trunk and head; (m) *trunk incurvation reflex (Galant):* credit is given when stimulation of the skin of one flank between rib and iliac crest causes lateral flexion of the trunk towards the side stimulated; (n) *placing response:* the dorsum of the child's foot is stimulated by placement against the edge of a table top; the child lifts his foot and places it on top of the table firmly; the stimulus is the pressure brought to bear on the dorsum of the foot against the table; it is investigated bilaterally; credit is given if the response is bilateral.

The data were recorded on precoded forms and were analyzed with a 370 IBM computer.

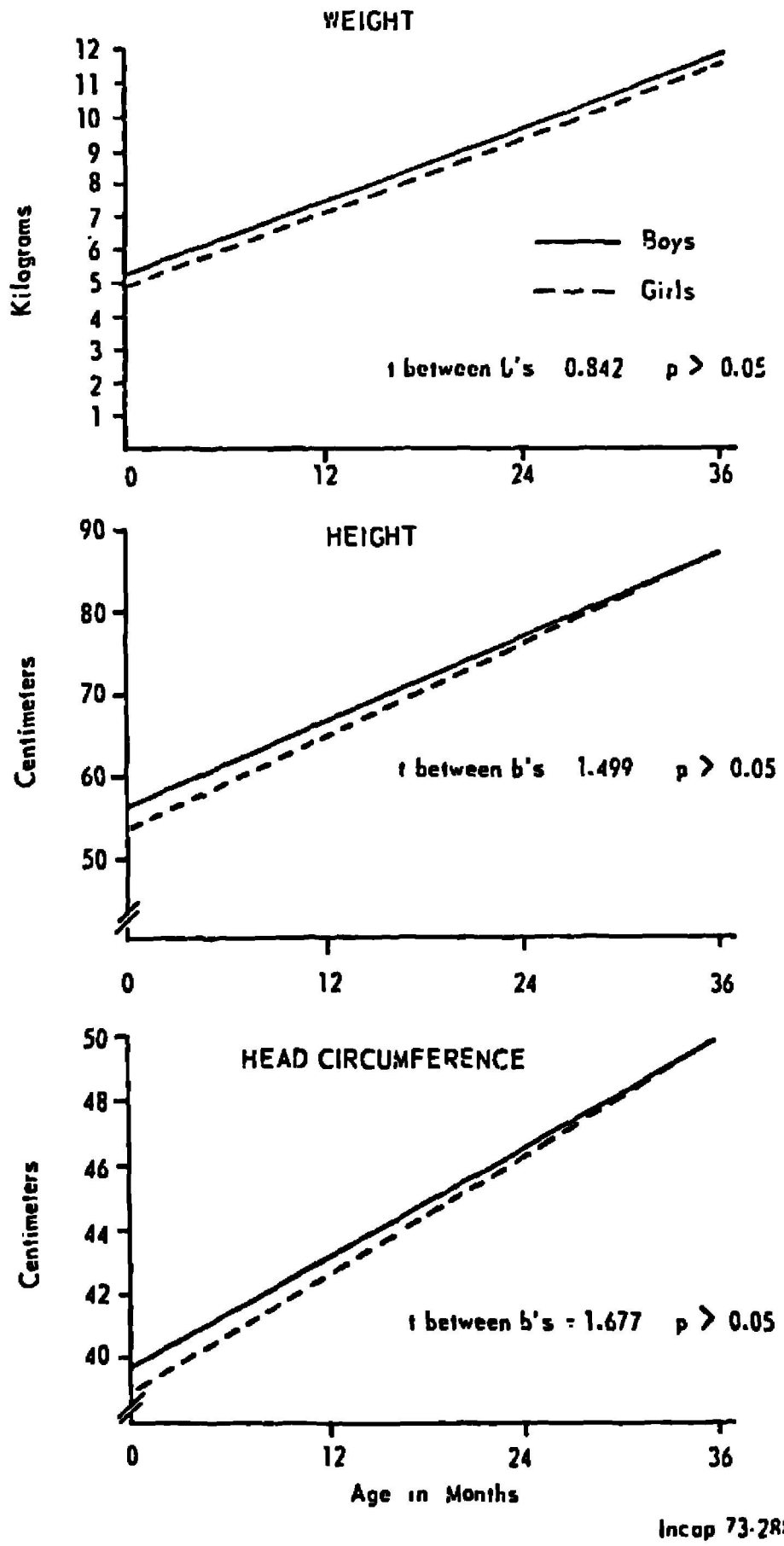

FIG. 2. Regression lines for height, weight and head circumference for male and female rural Guatemalan children (see text).

TABLE IV

PROBIT ANALYSIS:
16TH, 50TH, AND 84TH PERCENTILES FOR ALL NEUROLOGICAL FUNCTIONS, BOTH SEXES COMBINED, IN RURAL GUATEMALAN CHILDREN

	Percentiles		
	16*th*	50*th*	84*th*
Vertical Suspension			
Controls head	1.3	1.9	2.9*
Flexes arms 100% since 0 months			
Flexes legs 100% since 0 months			
Horizontal Suspension			
Flexes head	—	0.9	—
Head in line with body	0.7	0.9	2.3
Head in hyperextension	2.1	2.9	5.4
Extension of legs	1.0	2.2	3.8
Hyperextension of legs	6.4	11.2	20.6
Social			
Fixates on mother when spoken to	0.3	0.8	1.3
Social smile	0.7	1.2	1.8
Social laugh	3.9	5.6	10.8
Auditory Response			
Facial response to auditory stimulus	—	0.5	0.9
Turns the head to auditory stimulus	2.5	3.7	4.8
Visually Follows 4" Red Ball Horizontally			
30° with ease (more than 50% of the time)	—	0.5	1.1
90° with movement of the head	2.1	2.6	3.4
Visually Follows 4" Red Ball Vertically			
Less than 30°	—	0.4	0.9
More than 30°	—	1.0	2.1
More than 30° with head movements	2.0	2.8	4.2
Grasps Dangling Object (4" Red Ring)			
Movement of arms	1.2	2.1	2.7
Opens and closes fingers at a distance	1.2	2.9	4.1
Grasps dangling object	4.4	4.9	6.1
In Prone Position Approaches and Takes Object			
With both hands	4.4	5.0	6.1
Unilaterally	5.1	6.2	7.9
Fixates on object	--	0.2	0.5
Facial response to visual stimulus	—	0.2	0.7
Fixes vision on his hands	2.2	3.1	4.1
Puts hands in contact in midline	2.1	3.2	4.2
Removes handkerchief from face	4.1	5.0	6.1
Manipulates object with purpose	3.6	5.2	5.9
Transfers object from one hand to the other	4.6	5.6	6.9
Releases object voluntarily	8.2	10.3	11.8
Correlates hand opening with size of object	8.1	10.5	11.8
Prone Position			
Raises head, frees chin	0.6	1.0	2.2
Raises head <45°	1.5	2.8	4.1
Raises head >45°	2.1	3.2	5.4
Supports self on forearms	2.1	4.1	5.7
Supports self on hands	4.9	5.9	7.5
Rolls over from prone position	3.7	6.2	8.4
Rolls over from supine position	3.6	5.9	8.4
Kneels	6.6	8.4	10.0
Creeps (hands and knees)	7.1	10.0	11.8

TABLE IV—(*Continued*)

	Percentiles		
	16*th*	50*th*	84*th*
Traction Response			
Head lag without participation	—	2.1	—
No head lag without participation	1.7	3.1	4.8
No head lag with participation	3.9	5.4	7.0
Sitting			
Sits supported by arms	4.6	6.1	8.1
Sits alone	5.6	7.4	8.6
In Sitting Position Without Falling			
Follows 4" red ball horizontally	6.3	7.6	9.2
Follows 4" red ball vertically	6.3	7.7	9.2
Sustains sitting position with lateral push without overbalancing	6.3	7.9	8.7
Sustains sitting position with posterior push without overbalancing	8.6	14.5	23.5
Standing			
Primary neonatal type standing	2.7	2.2	0.9
Physiological astasia	0.4	2.2	2.7
Definitive standing	3.1	3.9	6.3
Locomotion			
Neonatal walking reflex	3.3	2.2	0.9
Abasia	0.3	2.0	2.9
Definitive walking	3.2	5.0	6.7
Walks holding rail	9.8	11.6	14.1
Walks with one hand held	11.8	13.8	17.6
Maintains balanced stance	12.4	16.2	20.6
From unsupported standing position sits down on floor unaided	11.8	16.2	20.6
Walks without support	13.0	17.2	21.7
Walks with flexion of knees and hips	17.6	21.2	25.4
Walks with heel touching floor before the plantar surface	17.6	21.2	24.8
Runs well	18.0	22.2	26.1
Pellet Testing			
Regards pellet	2.4	3.5	4.9
Rakes with hands	4.9	6.4	7.9
Rakes with radial border	6.4	8.4	9.6
Scissors grasp	7.6	8.6	11.2
Inferior pincer grasp	8.2	10.3	11.7
Fine pincer	10.2	11.5	16.0
Language			
Vocalizes in reply to social stimulation	1.0	2.8	7.0
Recognizes his name	7.9	9.2	10.6
Meaningfully uses "mama"-"papa"	9.4	10.8	14.9
Responds to "no"	9.0	9.8	13.2
Pat-a-cakes	9.1	10.0	14.9
Waves "bye-bye"	8.5	11.6	17.0
Understands "Give it to me"	9.9	11.5	13.5
Says 2–3 words	9.8	13.2	17.9
Short phrases	20.8	23.0	25.3
Sentences	21.7	26.0	30.6
Achieves Bladder Sphincter Control			
Daytime	21.3	28.6	34.5
Nighttime	22.2	36.5	—
Achieves Rectal Sphincter Control			
Daytime	18.0	28.0	29.4
Nighttime	19.2	28.4	37.0

TABLE IV-- (*Continued*)

	Percentiles		
	16th	*50th*	*84th*
Responses and Reflexes			
Palmar grasp	6.3	4.8	3.3
Plantar grasp	7.5	6.2	5.1
Sucking reflex	6.2	4.4	2.9
Rooting reflex	6.2	4.4	2.9
Crossed extension			
flexion, adduction and extension	6.5	4.1	2.9
cortical response	2.7	4.7	6.2
Tonic neck reflex	6.6	5.6	3.9
Moro (by hyperextension of head)			
arms extended	3.8	2.9	2.7
fingers extended	3.6	2.6	2.2
arms abducted	2.8	2.5	2.1
Moro (by extending hands and releasing)			
arms extended	4.4	3.0	2.7
fingers extended	3.5	2.8	2.1
arms abducted	2.8	2.5	2.1
Cochleopalpebral	100% since 0 months		
Withdrawal	100% since 0 months		
Parachute response (precipitation)			
contact on palms	6.9	7.8	9.5
supports body weight	7.2	7.9	12.5
hyperextension of the neck	7.1	8.0	9.9
Trunk elevation response			
(*redressement du tronc*)	6.3	4.0	0.4
Trunk incurvation reflex (Galant)	4.9	3.4	3.1
Placing response	5.3	3.1	2.2

* All ages are given in months.

RESULTS

Before presenting ages at which neurological functions are performed, it is necessary to determine if there are differences between Indian and Ladino children, and between males and females in physical development.

Table I shows the distribution of children by age, sex and race. Age and sex of the 58 Indian children are normally distributed in both sexes. A matched pair study was performed to test if they were different from the Ladino group in their anthropometric measurements. Table II shows the mean and t-test values for each group. Since differences between the groups are not significant, the Indian children and Ladino children are treated as a single group for purposes of analysis.

Height, weight and head circumference by age are shown in Figure 1 for boys and girls. The continuous line for height and weight represents the standards for well-nourished Central American children.[43] The standards for head circumference come from the weighted average of data from 14 reports in the world literature.[44] All the values for these three anthropometric measurements in the study population are far below the standards for both boys and girls. Figure 2 shows the regression lines for height, weight and head circumference on age, for boys and girls. Boys are taller, heavier and have a larger head circumference than girls, but in the three measurements the differences are greater at birth and tend to decrease with increasing age. When tested for differences in the slopes between the sexes for each anthropometric measurement, none of them was found to be significant. But although the differences were not significant this could be an indication that when boys get older they are more affected than girls in their physical growth characteristics.

Table III shows a correlation matrix between anthropometric measurements including age. With the single exception of height and weight which differs little between sexes, values for boys are consistently lower than those for girls. These differences were found to be significant at 0.05 level by the Wilcoxon Signed Rank Test.[45]

Despite the fact that boys are apparently more affected than girls by environmental insult, it was decided to pool the data in order to increase the sample size and estimate the parameters concerned with the timing of development of neurological skills. The implications of this decision will be discussed later.

TIMING OF NEUROLOGICAL SKILL DEVELOPMENT

Since this was a cross-sectional study dealing with quantitative data, it was thought that the most effective way of calculating the ages at which the functional levels of skill development were achieved was the probit analysis.[46,47]

Sixteenth, 50th and 84th percentiles for the various individual functions were calculated by this method. The reason for choosing these percentiles was that the 16th and 84th percentiles were an approximation to minus and plus one standard deviation, respectively. Table IV shows these results, both sexes combined. All the ages are given in months.

For some functions in which the development of the skills occurs early in life, sometimes before 1 month of age, it was not possible to calculate the 16th percentile. For bladder sphincter control at nighttime it was not possible to calculate the 84th percentile because at age 36 months more than 84% of the sample failed to pass this function.

As can be seen in Table IV most of the neurological functions followed a progression to the right. For example, in the items listed under vertical suspension, only 16% of the sample could control the head at age 1.3 months, 50% were able to control it at age 1.9 months and 84% at age 2.9 months. In other words the median age at which

children control their heads, in the study population, was at 1.9 months.

For responses and reflexes the timing shown in Table IV proceeded in the opposite direction. This phenomenon is a physiological one. In normal children these reflexes are present when they are born and tend to disappear in the first months of life. Some of them, such as cochleopalpebral and withdrawal reflexes, were reported as present in all children.

DISCUSSION

In the present study the findings with respect to anthropometric measurements demonstrate clearly that this group of children living in an impoverished area was far behind the norms against which they were compared.

Height and weight of children in the study population were compared with standards from well-nourished Central American children with similar genetic characteristics. Head circumference was compared with standards from several reports in the literature in which there were no significant racial, national or geographic differences. The correlations among these three anthropometric measurements all were above 0.850 for both boys and girls. Thus any of these measurements could be used as a criterion of degree of deficiency in growth.

It was noted that correlations between anthropometric measurements were systematically higher in girls. Also girls seemed to progressively approach the norms in those measurements, and at age 36 months differences between the sexes were considerably less than at birth. If the sexes were affected in the same way the differences would be expected to remain constant.

It was considered that the sample was not big enough to detect differences between the sexes in regard to timing of neurological skills. Given the relatively small number of cases it was decided to pool the data even though differences existed between boys and girls in anthropometric measurements. Fifty-eight children that were classified as Indian did not differ from the Ladino group in their physical growth characteristics. This does not mean that the Indian and Ladino groups necessarily grow at the same rate. One of the reasons for finding no differences between them could be the small number of Indians scattered in the total sample. It has to be pointed out also, that neither group was 100% Indian or Spanish, since mixture of races is not infrequent and sometimes it is difficult to classify them as belonging to a specific ethnic group. There was no reason, then, to treat the Indians as a separate group.

The genetic characteristics of the rural children in this sample were presumably similar to those of the population from which the Guatemalan standards were derived. If so, then it would be expected that both groups would be similar in their physical growth unless environment interfered with growth. When the child is living under ideal conditions it is reasonable to suppose that his growth and maturation are determined mainly by heredity. In other words he should be able to realize the full growth potential available in him. Obviously the Guatemalan rural children were not living under ideal conditions. They were suffering from poor nutrition[35] and had a high incidence of communicable diseases.[43]

Although developmental retardation could be a reflection of several environmental interferences, stunting of growth, indicated by below average weight, height, and head circumference, is more likely to be produced by inadequate food intake and its interaction with acute or chronic illness.[32,48,49]

Results on the timing of skill development for individual neurological functions are presented. It has to be considered that this is a cross-sectional study of a small sample. From the epidemiological point of view an incidence or prospective study is a more powerful and sensitive method to obtain accurate information about the occurrence of new events in a population and the relation of cause and effect than is a prevalence study.

Unfortunately no comparisons in timing of skill development can be made between this sample and other populations since there is little in the literature on patterns of neurological development from population-based studies.[50-52] One of the possible comparisons is in respect to age of walking. Hindley and his colleagues[53] reported the median age of walking, from five European longitudinal studies, of 13.1 months. The 50th percentile for the Guatemalan children is 17.2 months. Thus the Guatemalan children were more than four months behind European children in the time they started to walk.

In the present study it is not possible to say to what extent the sample population is affected by environmental factors in its neurological development. It is assumed that if the rural Guatemalan children are far behind in their physical growth when compared to well-nourished Central American children, they may also be affected in their neurological development.

SUMMARY

A cross-sectional study of anthropometric measurements and neurological evaluation of 559 Guatemalan rural children (286 boys and 273 girls) from 0 to 36 months of age was performed.

Height and weight were compared to standards

from the Institute of Nutrition of Central America and Panama (INCAP). Head circumference was compared to standards from 14 different studies compiled from the world literature. The analysis of the data showed that this group of children is far behind the standards in their physical growth characteristics.

The neurological evaluation was performed by two pediatricians who had a careful period of standardization in techniques and methods of evaluation before the beginning of the study.

Results were presented in the timing of skill development. The 16th, 50th and 84th percentiles for individual neurological functions were calculated by the probit method that is a more powerful method of analyzing this kind of data than the simple cumulative percentage. These results should not be taken as patterns or norms but rather as a baseline for future studies.

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"Every great university must balance its responsibilities to the worlds of reflection and action . . . A society that aspires to creativity has urgent need of its detached scholars and critics, as well as those who will become deeply involved in the world of action . . . The life of reflection is not superior to the life of action, or vice versa. Both are essential to a vital society."

J. W. Gardner