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Relationship of maternal and infant nutrition to infant growth *

Hernán L. Delgado, Victor E. Valverde,
Reynaldo Martorell ** and Robert E. Klein

Division of Human Development, Institute of Nutrition of Central America and Panamá (INCAP), Guatemala, Guatemala

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Summary

A cohort of all infants born between January 1, 1969 and February 28, 1977 in four rural villages in Eastern Guatemala which were participating in a longitudinal project of nutrition and mental development was studied. As part of the study, prospective information on anthropometric measurements, morbidity, dietary intake and socioeconomic and cultural characteristics was collected. In addition, two types of food supplements were distributed: calorie and protein-calorie. Attendance at the feeding centers in each village and the amount of supplements consumed by children and pregnant and lactating mothers were recorded daily. We studied the effect of the supplements consumed by the mother during pregnancy and lactation and by the infant on trimestral infant weight and length changes during the first year of life. The data indicate that infant calorie supplementation before three months of age is significantly and negatively associated with infant growth; after three months of age, supplemental calories consumed by the infant are significantly and positively associated with infant weight and length gains. In addition, a small positive association was found between maternal caloric supplementation during lactation and infant growth during the first two trimesters of life, after controlling for potentially confounding factors for which data are available in this study.

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** *Present address:* Food Research Institute, Stanford University, Stanford, California, U.S.A.
Address for correspondence: Dr. Hernán L. Delgado, Division of Human Development, Institute of Nutrition of Central America and Panama (INCAP), P.O. Box 1188, Guatemala, Guatemala.

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Introduction

There is considerable indirect evidence that maternal malnutrition during preg nancy and lactation is one of several factors contributing to postnatal growtł retardation [1,13,15]. Maternal nutritional status is associated with the output oı breast milk during lactation [4,8] which, in turn, is an important determinant of earl) postnatal growth in breast-fed infants. In addition, higher morbidity rates durinį infancy are associated with inadequate breast-feeding performance [3,5] and the consumption of food by the infant is also correlated with infant growth [6,9]. These interrelationships of maternal and infant nutrition to infant growth have been difficult to explore in humans because the experimental conditions cannot be precisely controlled. Human malnutrition is commonly associated with lack of education, lack of resources and services, and increased disease incidence that mutually influence one another.

This paper examines the interrelationships between maternal nutrition, breast-feeding, infant nutrition and infant growth in the context of a quasi-experimental longitudinal investigation carried out in rural Guatemala. Previous publications have described in detail the population, the experimental design and methodology of this study and have reported that caloric supplementation during pregnancy improved birth weight and reduced infant mortality]15–17]. This is the first publication from the Guatemalan study to focus on the relationship of maternal and infant nutrition to infant growth during lactation utilizing all data collected between 1969 and 1977.

Materials and Methods

The subjects were inhabitants of four agricultural villages participating in a longitudinal study of the relationship between malnutrition, physical growth and mental development, which was conducted between 1969 and 1977. The specific characteristics of the study population have been described in detail elsewhere [14,16].

Table I presents the significant features of the design. One of two types of supplement, a protein-calorie one ('atole', a gruel commonly made with corn) and a caloric supplement ('fresco', Spanish for a refreshing, cool drink), was provided in each of the four participating villages. Attendance and consumption at the food supplementation center was free and voluntary and this resulted in a wide range of supplement intake in the study population. In addition, with the initiation of the study, clinics were established in the communities and free primary medical care was provided to the population.

The entire population of the four communities was 3359 in 1975. The sample for

TABLE I

Experimental design

Type of supplement	Number of communities	Protein-calorie supplements	Calorie supplements	Vitamins and minerals	Outpatient medical care	Nutrient content of supplements per 180 ml	
						Total calories (kcal)	Protein (g)
'Atole'	2	+	+	+	+	163	11.0
'Fresco'	2	−	+	+	+	59	0

these analyses was all children born between January 1, 1969 and February 28, 1977 ($n = 1106$) and who were followed up to 12 months of age. Data collection procedures and the variables used in this study are described below.

Data on a variety of anthropometric measurements were taken by trained and standardized anthropometrists at specific ages (15 days, 3, 6, 9 and 12 months for children and quarterly for mothers during pregnancy and lactation). Infant weight and length and maternal weight change during lactation were selected as indicators of nutritional status. These variables were measured with high reliability [18].

The main independent variable is nutrient intake, which includes supplement consumed at the feeding center and home diet and supplement intake. The consumption of 'fresco' and 'atole' was recorded to the nearest 10 ml and is expressed in terms of calories because the normal dietary intake appeared to be more limited in calories than in proteins. The food supplementation program was found to increase variability in nutrient intake and to provide a true supplement to the habitual diet of pregnant mothers and preschool children [17,19]. Dietary recall data were collected at the end of each trimester of pregnancy beginning in 1969. For the present analyses, dietary information for the last two trimesters of pregnancy was averaged to provide an estimate of usual home energy intake for each woman.

After 1974, the same 24-hour recall method was utilized to collect information on home dietary intake for lactating mothers and infants. Home dietary intake and supplement consumption were summed to produce an estimate of total energy intake. This measure is available for pregnant women for the period 1969–1977, and for infants and lactating women for the period 1974–1977. Energy intake of the infant does not include the contribution of breast milk. In addition, after 1974, the recall method was utilized to collect information on frequency of suckling. The mother was asked the number of times the child was put to the breast during the preceding day.

Maternal morbidity during pregnancy and lactation, and infant morbidity were obtained from biweekly, retrospective, symptom-oriented home surveys. A morbidity indicator combining the incidence of diarrhea and other common illnesses was used as the indicator for both maternal and child morbidity. This survey was also used to monitor lactation in all women in the study population. Information on whether or not the infant was breast-feeding was obtained.

Finally, other variables, including socioeconomic status of the family, paternal characteristics such as age and height, and maternal characteristics were also utilized in the analysis.

Results

Descriptive statistics

Mean daily supplemental and total energy and protein intake (the sum of home diet and food supplement) for mothers during pregnancy and lactation and for infants in 'atole' and 'fresco' communities are shown in Table II. Energy and protein

TABLE II

Mean for caloric and protein supplement intake and total nutrient intake of mothers and children * in 'fresco' and 'atole' villages

	'Fresco'				'Atole'			
	Energy (kcal/day)		Protein (g/day)		Energy (kcal/day)		Protein (g/day)	
	Supplement	Total caloric intake	Supplement	Total protein intake	Supplement	Total caloric intake	Supplement	Total protein intake
Mothers								
Pregnancy	81±71 **	1528±447	0	42.8±12.3	107±95	1592±432	7.5±6.7	50.2±13.3
Lactation								
3 months	34±47	1698±587	0	48.2±19.8	134±153	1826±556	9.5±10.8	61.9±20.1
6 months	60±75	1701±586	0	47.5±17.5	175±199	1825±636	12.3±14.0	62.7±22.9
9 months	61±77	1679±595	0	47.7±19.4	150±185	1796±583	10.6±13.0	61.1±21.2
12 months	60±76	1604±561	0	47.3±20.3	128±171	1798±616	9.0±12.1	60.1±22.5
Children								
Infancy								
3 months	1±4	63±116	0	0.7±1.5	38±50	79±85	2.7±3.6	3.7±3.6
6 months	4±8	112±178	0	1.4±2.8	60±83	152±155	4.2±5.9	6.4±6.6
9 months	5±9	211±208	0	4.3±4.6	62±90	282±226	4.4±6.4	9.9±8.6
12 months	6±10	411±256	0	8.1±5.9	66±93	458±247	4.7±6.6	13.6±9.4

* Both sexes combined.

** Mean±S.D.

TABLE III

Percentiles for weight (kg) by sexes in rural Guatemalan 'ladino' infants

Age	Girls							Boys						
	n	$\bar{x}\pm$S.D. *	Percentiles					*n*	$\bar{x}\pm$S.D.	Percentiles				
			3	25	50	75	97			3	25	50	75	97
15 days	287	3.22±0.47	2.34	2.88	3.24	3.56	4.01	324	3.38±0.50	2.48	3.05	3.40	3.73	4.24
3 months	427	5.19±0.71	3.81	4.72	5.20	5.70	6.50	465	5.59±0.82	3.90	5.09	5.70	6.10	7.02
6 months	425	6.56±0.88	4.87	6.04	6.54	7.08	8.22	479	7.00±1.00	4.84	6.39	7.05	7.63	8.80
9 months	414	7.17±0.95	5.30	6.56	7.18	7.72	9.12	470	7.66±1.04	5.60	7.00	7.67	8.32	9.58
12 months	404	7.59±1.01	5.70	6.90	7.60	8.23	9.68	445	8.12±1.11	5.89	7.40	8.12	8.81	10.30

* Mean±S.D.

TABLE IV

Percentiles for length (cm) by sexes in rural Guatemalan 'ladino' infants

Age	Girls							Boys						
	n	$\bar{x}\pm$S.D. *	Percentiles					*n*	$\bar{x}\pm$S.D.	Percentiles				
			3	25	50	75	97			3	25	50	75	97
15 days	298	49.1±2.0	45.0	47.8	49.3	50.5	53.0	326	50.0±2.4	44.8	48.8	50.2	51.6	54.0
3 months	427	56.6±2.2	52.3	55.2	56.7	58.0	60.5	466	58.0±2.4	53.0	56.6	58.2	59.6	62.0
6 months	420	62.0±2.2	57.8	60.5	62.0	63.4	66.2	477	63.5±2.5	58.0	62.0	63.6	65.1	67.6
9 months	414	65.2±2.7	60.0	63.8	65.4	66.8	69.5	472	66.7±2.7	61.0	65.2	67.0	68.5	71.3
12 months	403	68.0±2.7	62.5	66.5	68.0	69.7	73.0	443	69.5±3.0	63.1	67.7	69.8	71.3	75.0

* Mean±S.D.

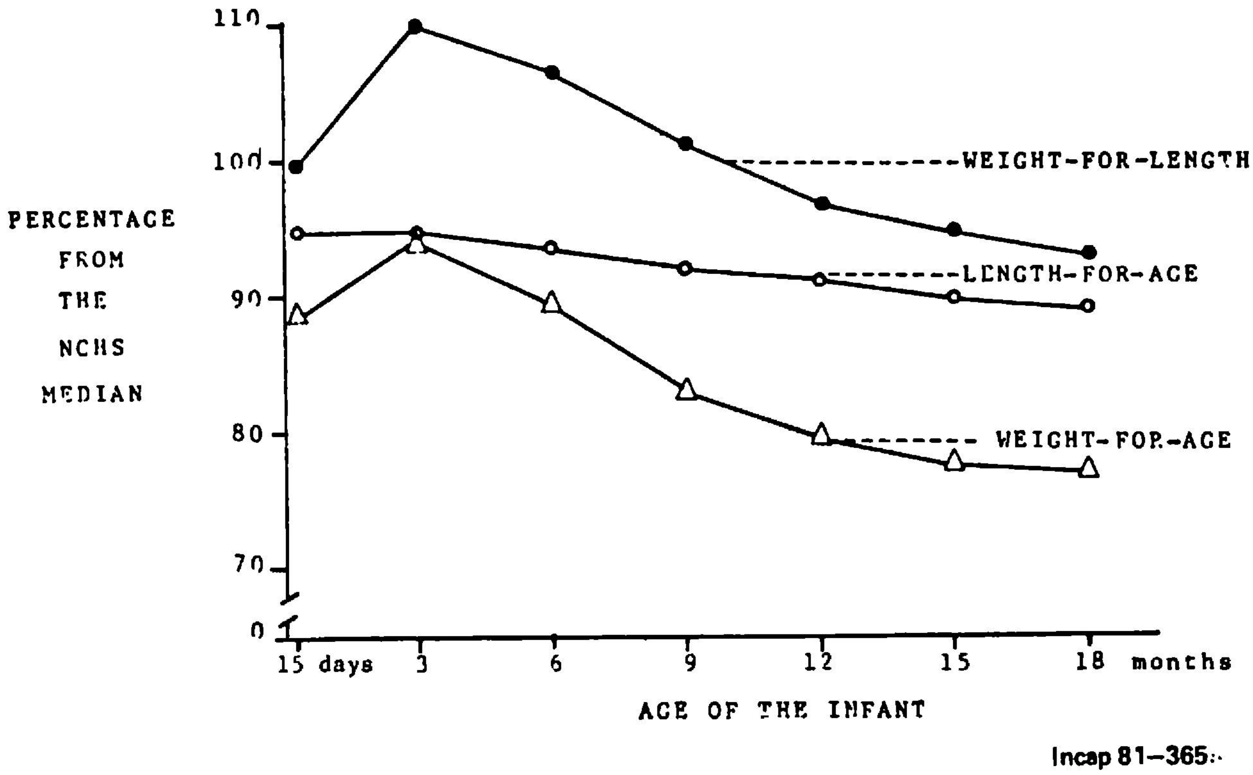

Fig. 1. Comparison between length and weight in rural Guatemalan children and NCHS children.

intakes during pregnancy are lower than during any of the trimestral lactation periods in both types of communities.

Furthermore, the energy and protein intake of infants derived from food sources other than breast milk is very low. At 12 months this may represent approximately 50% of the FAO/WHO energy requirements [20] for their actual weights. The size of standard deviations as compared to the mean energy and protein intakes up to 9 months of age indicate that a great proportion of children were in fact not consuming any foods other than breast milk.

Sample size by age groups, mean length and weight, standard deviation and age specific percentiles for both length and weight for boys and girls from 15 days to one year of age, are shown in Tables III and IV. Boys are taller and heavier than girls at all ages studied ($P < 0.01$).

In Fig. 1, a comparison with National Center for Health Statistics (NCHS) age and sex specific percentiles is shown [12]. Relative differences in weight and length for age, as compared to the median values for NCHS children, indicate that length retardation increases gradually through the first year, while weight retardation is more obvious after three months of age.

These results suggest that infant weight is more readily affected than length. The comparison of body weight-for-length, also included in Fig. 1, confirms this notion.

Nutrition and infant growth

To explore the effect of maternal and child energy intake on infant growth, the magnitudes of the simple correlations were calculated between measures of intake (caloric supplementation, home caloric intake and total caloric intake) and attained and incremental infant weight and length within and between 'fresco' and 'atole' villages. No significant differences were found between 'fresco' and 'atole' supplements, and thus all the data were pooled and a nominal variable (0 = 'fresco'; 1 = 'atole') was utilized in all further analyses to identify the type of supplement given to the infant.

Correlation coefficients between measures of trimestral maternal nutritional intake during lactation (0 to 3; 3 to 6; 6 to 9, and 9 to 12 months of lactation) and attained (at 3, 6, 9 or 12 months of age) or incremental (from birth to 3; 3 to 6; 6 to 9, and 9 to 12 months of age) infant weight and length showed: (1) significant positive associations between maternal nutrient intake during lactation and infant weight at 3, 6, 9 and 12 months of age and infant length at 6, 9 and 12 months of age; (2) positive and significant associations between trimestral maternal nutritional intake during lactation and increments in weight from birth to 3, 3 to 6, 6 to 9, and 9 to 12 months, and increments in length from 3 to 6 months of age. Furthermore, positive and significant associations were found between measures of trimestral infant nutritional intake after 3 months of age (3 to 6, 6 to 9, and 9 to 12); and (1) attained weight and length at 6, 9 and 12 months of age, and (2) incremental weight and length from 3 to 6, and 6 to 9 months of age.

The question of whether non-nutritional factors (i.e., confounding factors which influence infant growth and are correlated with nutritional intake) were responsible for the observed associations was addressed by using multiple regression analyses. In the regression equation, the dependent variable was the change in either trimestral infant weight or length (0–3, 3–6, 6–9, and 9–12 months of age). The independent variables, specific to the trimester being analyzed, were caloric supplementation for the mother, caloric supplementation for the infant, maternal home diet during pregnancy, morbidity of the mother, morbidity of the infant, maternal weight change, maternal anthropometry (height and head circumference), father's age and weight, maternal obstetrical characteristics (age, parity and interval from prior delivery), socioeconomic status of the family, and infant characteristics at birth (sex, birth weight and gestational age). Furthermore, in order to control for a particular pattern of growth or nutrient intake, information on incremental weight and length, and maternal and infant caloric intake for the previous trimester were also considered in the regression model. For the particular case of the first trimester after birth, information on maternal supplementation during pregnancy, and infant length at 15 days of age were introduced as independent variables. Finally, 'dummy' variables, such as sex of the infant (1 = male, 2 = female), type of supplement given to the infant (0 = 'fresco'; 1 = 'atole') and whether or not the infant was breast-feeding during a given trimester (0 = no, 1 = yes) were also considered in the model. In summary, the multiple regression equations considered a set of independent and 'dummy' variables to predict trimestral infant weight changes or trimestral infant length changes, after controlling for the previous pattern of food consumption of the mother and of the infant, and for the previous pattern of infant growth. This statistical procedure has been described in great detail elsewhere [7].

Table V (page 282) presents the regression coefficients and significance values after all independent and 'dummy' variables were entered in each of the eight specific multiple regression analyses described above. As shown in Table V, after 3 months of age, caloric supplementation ingested by the infant is significantly and positively associated with weight and length increases. Prior to 3 months of age, supplemental calories consumed by the infant are significantly and negatively associated with his/her weight gain, and caloric supplementation to the mother during the last trimester of pregnancy is significant and positively associated with increased infant length. Caloric supplementation consumed by the mother during lactation is not significantly related to infant growth (neither weight nor length). However, at 0–3 and 3–6 months, an almost significantly ($0.05 < P < 0.10$) positive association between supplemental calories ingested by the mother, and infant weight gain, is observed. The value of the slope (*b*-value) between maternal caloric supplementation and infant weight gain becomes less important after 6 months of age. Other variables significantly associated with infant weight and length gain are also listed in Table V. To avoid complicating this table, only the signs (+ or –) of the significant associations are shown. However, it should be pointed out that, in addition to infant supplementation, height and head circumference of the mother, and the father's height are significantly and positively associated with both weight and length gain. Parity and interval from prior delivery are also associated to incremental growth in the expected direction, and breast-feeding during the trimester is significantly and positively correlated with weight and length changes after 6 months of age. Before 6 months of age, practically all children were breast-fed. Finally, at 3 months of age, a significant difference in growth between 'atole' and 'fresco' communities was observed, indicating that factors associated with the 'atole' population, and not controlled in the multiple regression analysis, are responsible for a higher weight gain in the 'atole' than in the 'fresco' communities at 3 months of age.

The nature of the relationship between past weight and length gains, and present weight and length changes can be examined from the same multiple regression analyses, although it is more difficult to interpret. Table VI, presents the regression coefficients of the association between birth weight and length at 15 days, on the one hand, and weight and length changes from birth to 3 months of age, on the other. It was found that infants who were short at birth experienced greater gains in length by 3 months of age, yet at the same time, infants who were heavy at birth also experienced greater gains in length. Exactly the opposite occurs in the case of weight gain from birth to 3 months of age: infants who were light at birth experienced greater gains in weight, but at the same time, long neonates tended to experience greater weight gains. In summary, short–heavy neonates gained considerably more length and less weight than long–light neonates.

As shown in Table VI after 3 months of age, the same tendency to approach a more normal weight for length relationship was found. When length gain is studied, greater gains in length follow greater gains in weight and smaller gains in length as compared with the previous trimester. On the other hand, no clear pattern emerges from weight changes after 3 months of age.

Finally, analyses were performed on a subset of the study sample which includes all infants born after 1974 and for whom more complete information on home

TABLE V

Relationship between maternal and infant calorie supplementation and trimestral infant weight and length changes. Multiple regression of trimestral weight gain and length gain

Age period	Main independent variable: supplement calories consumed by	Weight changes = slope (*b* value) g/1000 supplemental calories/trimester	Length changes = slope (*b* value) mm/1000 supplemental calories/trimester
Birth (or 15 days) to 3 months	Mother: last trimester of pregnancy	2.9	0.25 *
	Mother: first trimester of lactation	5.1	-0.10
	Infant: 0–3 months of age	-29.7 ***	-0.23
	Number of cases	891	537
		Other variables in the model significantly associated with the dependent variable	
		(−) sex of newborn; (+) gestational age (−) birthweight; (+) length at 15 days (+) maternal height; (+) maternal head circumference (+) birth interval; (+) 'fresco'/'atole'	(−) sex of newborn; (+) birthweight (−) length at 15 days; (+) maternal height (+) father's height; (−) parity
3 to 6 months	Mother: second trimester of lactation	4.9	0.60
	Infant: 3–6 months of age	15.8 **	0.73 ***
	Number of cases	617	612
		Other variables in the model significantly associated with the dependent variable	
		(+) infant's weight gain 0–3 months	(−) birthweight; (−) infant's length gain 15 days–3 months (−) parity

6 to 9 months	Mother: third trimester of lactation	3.4	0.07
	Infant: 6–9 months of age	12.7 *	0.40 **
	Number of cases	650	645
		Other variables in the model significantly associated with the dependent variable.	
		(+) maternal height	(+) infant's weight gain 3–6 months (−) infant's length gain 3–6 months (+) maternal height; (−) infant morbidity; (−) weaned; (+) 'fresco'/'atole'
9 to 12 months	Mother: fourth trimester of lactation	1.7	0.01
	Infant: 9–12 months of age	21.4 ***	0.36 *
	Number of cases	641	640
		Other variables in the model significantly associated with the dependent variable	
		(−) infant's weight gain 6–9 months	(+) infant's weight gain 6–9 months (−) infant's length gain 6–9 months (+) father's height; (−) infant's supplementation 6–9 months

* $P<0.05$; ** $P<0.01$; *** $P<0.001$

TABLE VI

Relationship between prior trimestral weight and length gains and subsequent trimestral weight and length changes. Multiple regression of trimestral weight and length gains *

Age period	Independent variables	Dependent variables	
		Weight changes (slope (*b* value)= g/g or g/mm)	Length changes (slope (*b* value)= mm/g or mm/mm)
Birth or 15 days	Birthweight	−0.50 **	0.005 ***
	Length at 15 days	9.08 **	−0.38 ***
3 to 6 months	Weight change 0–3	0.06 *	0.001
	Length change 0–3	1.50	−0.22 ***
6 to 9 months	Weight change 3–6	0.00	0.009 ***
	Length change 3–6	0.31	−0.23 ***
9 to 12 months	Weight change 6–9	−0.10 *	0.005 ***
	Length change 6–9	−2.16	−0.12 ***

* After controlling for suspected confounding factors.

dietary intake during lactation and frequency of suckling was available. In these analyses, the multiple regression model was expanded to include measures of total nutrient intake of the mother and of the infant during lactation and a measure of the frequency of suckling. The results from these analyses are similar to those previously presented. Two findings are relevant: first, dietary intake of the infant from 0 to 3 months of age is significantly and negatively correlated with weight changes in that interval, and second, maternal dietary intake from 3 to 6 months postpartum is significantly and positively correlated to infant weight gain from 3 to 6 months of age.

Discussion and Speculations

Maternal malnutrition during pregnancy and lactation, and infant nutrient intake have been cited as two important factors contributing to postnatal growth retardation. In general, the results of INCAP's longitudinal study attest to an effect of maternal dietary supplementation on infant growth, particularly infant weight gain from birth to 3 months and from 3 to 6 months of age. The data also indicate that infant supplementation before 3 months of age is significantly and negatively correlated with infant growth, after controlling for potentially confounding factors for which data are available in this study. After 3 months of age, supplemental calories consumed by the infant are significantly, positively correlated to infant weight and length gains. The small association between maternal food supplementation and infant growth could be due, in part, to the fact that only a small fraction of the energy consumed by the infant is utilized for growth after the first trimester of age [2], and infant adaptation to limited caloric intake could be achieved by a reduction of physical activities [11]. The negative association between infant supplementation and infant growth is possibly due to the fact that mothers whose infants were not growing adequately began to give supplement to the infant earlier than those with more adequate growth.

The results also reflect the previously reported relationship between such factors as anthropometric measurement of the parents, obstetrical characteristics, infant morbidity, lactation and infant growth.

An effect of prior patterns of growth on subsequent growth was also observed. This result is consistent with that of Fergusson et al. [10], who reported that 'growth in the immediate post-natal period acts in a redistributative fashion which tends to stabilize the relationship between the child's length and weight'. Present findings indicate that the same interrelationship between prior patterns of infant weight and length gains exists for subsequent length changes up to one year of age. The results of this study and those of Fergusson et al. [10] support the utilization of combined length and weight measures instead of isolated measures (i.e., birth weight) to describe infant growth. These results also address the concept of catch-up growth and its implications for infant development.

Final Comments

In summary, an improvement in the nutritional status of pregnant and lactating women should have a positive impact on the physical growth of breast-feeding infants. Furthermore, the introduction of food supplements after 3 months appears to be essential in order to sustain normal growth in this population. Given the present lack of adequate alternatives to breast-feeding in poor rural areas of developing countries, it should be recommended that breast-feeding be promoted and that the mother be educated to enable her to recognize when a child is not following the 'normal' growth pattern and to take appropriate action. Finally, more research is needed regarding weaning foods which would be suitable for such populations in terms of cultural practices and economic resources.

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