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Chapter 11

Maternal Nutrition—Its Effects on Infant Growth and Development and Birthspacing

Hernan Delgado, Aaron Lechtig, Charles Yarbrough, Reynaldo Martorell, Robert E. Klein, Marc Irwin

The prevalence of low-birth-weight infants (≤2.5 kg) ranges between 13% and 43% in the low socioeconomic groups of many countries (38). Moreover, the frequency of physical growth retardation during the first year of life is widespread. These babies have a low survival rate during the first year of life and perform poorly on mental development tests (8, 9). It is widely believed that environmental factors account for most growth failures, developmental retardation, and high mortality rates.

Maternal and child malnutrition has been implicated as one of several environmental factors capable of producing these high rates of growth, developmental retardation and infant mortality. Moreover, several investigators have postulated that environmental factors such as health and nutritional status affect the duration of birth interval (25, 27, 55). However, this assertion is difficult to substantiate because of the imprecision involved in defining maternal and child nutritional status and because of a lack of information concerning the effects of several factors which may constitute alternative explanations of the detected associations.

This chapter examines alternative explanations through a food supplementation study which was carried out in a chronically malnourished population. The effect of food supplementation during pregnancy and lactation on 1) fetal growth, 2) infant growth, 3) psychologic test performance, and 4) infant mortality in the study population will be reported in addition to environmental factors correlated with the duration of birth interval.

INSTITUTE OF NUTRITION OF CENTRAL AMERICA AND PANAMA LONGITUDINAL STUDY

The Institute's longitudinal study has been well described elsewhere (16, 33); however, a brief description follows.

*This research was supported by Contract N01-HD-5-0640 from the National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, Md.

POPULATION

In 1969, a longitudinal study of the biologic and socioeconomic determinants of physical growth and mental development in rural Guatemala was begun. The project involved four small villages of eastern Guatemala. The ethnic background of the population is Ladino, or mixed Indian and Spanish. These are agricultural villages, and the main crops are corn and beans, most of which are consumed in the same village. Houses are built from material obtained locally, mainly adobe, and consist of two rooms, one of which is used as sleeping quarters by the whole family. The total population of the four villages is about 3500, half of the inhabitants being below 15 years of age. The number of previous deliveries among the women studied range between 0 and 12, and the reproductive span is from age 14 to 46. Approximately 160 children are born each year in the four villages combined.

There is little permanent migration, and contact with the outside world is limited to trips to nearby markets. Seasonal migration occurs once a year when some of the men harvest cash crops in the coastal zone. The median annual income is approximately $200.00 per family, with most expenditures allocated for food and clothing. Modern contraceptive practices are uncommon. Sanitary conditions are poor, leading to a high prevalence of infectious diseases, especially those of diarrheal nature. Drinking water is obtained from wells or a creek, and only 6% of the houses have latrines. Within the study villages, moderate malnutrition is endemic.

DESIGN

The basic hypothesis of this study was that mild to moderate protein-calorie malnutrition adversely affects the mental development of infants and preschool-aged children. To test the hypothesis, a quasi-experimental design was employed. Experimental treatment consisted of food supplementation in four closely matched villages. In two of the villages, a high protein-calorie supplementation drink was made available daily in a central dispensary. This beverage is similar to a popular local gruel, *atole.* In the other two villages, a non-protein, low-caloric drink similar to a local cold drink known as *fresco* was provided daily. The nutrient content of both supplements is shown in Table 11-1.

The low-caloric beverage, or fresco, contained no protein and provided only one-third of the calories contained in an equal volume of atole. Both supplements contained the vitamins, minerals, and fluoride which were limited in the normal diet. The subjects under study were children 7 years old and under, and all pregnant and lactating women in the four villages. Since consumption of the supplements was voluntary, a wide range of supplement intake during pregnancy and lactation in mothers and in infants was observed. In addition to dietary supplementation, all four villages received preventive and curative medical care.

Table 11-1. NUTRIENT CONTENT PER CUP* (180 ML) OF SUPPLEMENTATION DRINK

	Atole†	Fresco‡
Total calories (kcal)	163	59
Protein (g)	11	—
Fats (g)	0.7	—
Carbohydrates (g)	27	15.3
Ascorbic acid (mg)	4.0	4.0
Calcium (g)	0.4	—
Phosphorus (g)	0.3	—
Thiamine (mg)	1.1	1.1
Riboflavin (mg)	1.5	1.5
Niacin (mg)	18.5	18.5
Vitamin A (mg)	1.2	1.2
Iron (mg)	5.4	5.0
Fluor (mg)	0.2	0.2

*Review date: October 11, 1973; figures rounded to the nearest tenth.
†The name of a gruel commonly made with corn.
‡Spanish for refreshing, cool drink.

Table 11-2. DATA COLLECTED IN INCAP LONGITUDINAL STUDY

Maternal and child information

Independent variable:

- Measurements of subject's attendance to feeding center and amount of supplement ingested

Dependent variables:

- Assessment of physical growth
- Assessment of mental development
- Infant mortality
- Birth Interval

Additional variables:

- Obstetric history*
- Information on delivery
- Clinical examination
- Dietary survey
- Morbidity survey
- Socioeconomic survey of the family

*Diagnosis of pregnancy by absence of menstruation.

METHODS

The principal examinations made during the prenatal and postnatal period are presented in Table 11-2. Data collected were standardized carefully, and the data collectors were systematically rotated among the four study villages.

Ingestion of additional calories was selected as the criteria to assess supplement intake because the home diet appeared to be more limited in calories than in proteins. The variables were the prevalence of physical growth retardation at birth and 6 months of age, psychologic test performance at birth and 6 months of age, infant mortality, and birth interval.

In the study population, the protein/calorie ratio in the home diet is approximately 11%. Thus, we believe it is feasible to improve the total diet of mothers by adding more calories. While calories appear to be limited in this study population, other populations may present very different nutritional situations.

In the following analyses, caloric intake since conception will be expressed as both a continuous and a discrete variable. Two continuous variables are employed, maternal caloric intake during pregnancy and intake during lactation. In some analyses, these two components are combined into one summary variable. The limits defining the categories comprising the discrete variables are presented in Table 11–3.

Up to 6 months of age, the categorization of nutritional status depends only on the intake of the mother. Except for the rare case of severe maternal illness, all children are breast-fed to the age of 6 months and most do not receive supplementary foods. In constructing long-term categories, it was found that the sample sizes for the high-caloric supplement group would be very small if it were required that the mother be in the group during all three trimesters. Consequently, high-calorie supplemented children were defined as those well-supplemented during 75% of the periods. This definition is considered sufficiently strict to generate useful nutritional status evaluations.

Table 11–4 presents the sample sizes for each of the variables examined. The total sample included 671 births which occurred in the four villages from January 1969 through February 1973.

EFFECT OF MATERNAL NUTRITION ON FETAL GROWTH

The effect of maternal nutrition on birth weight under situations of acute starvation is clearly established (1, 28, 54). On the other hand, studies concerning the influence of chronic moderate malnutrition on fetal growth have shown less

Table 11–3. DEFINITION OF LOW, INTERMEDIATE AND HIGH CALORIC SUPPLEMENTATION STATUS SINCE CONCEPTION

1. Description of the Scoring for Each Time Interval

		Criteria to be defined as: (Supplemented Calories in thousands)		
Time intervals (months)	Subject	Low	Intermediate	High
Pregnancy	Mother	< 10	10–19.9	≥ 20
0–3	Mother	< 5	5–9.9	≥ 10
3–6	Mother	< 5	5–9.9	≥ 10

2. Summary Periods	**Total Number of Time Intervals**	**Minimum No. of Time Intervals in the same category**
1. Pregnancy	2	2 (100%)
2. Conception to 6 months	4	3 (75%)

3. An infant is classified as Low or High if his mother has ranked in the same category for at least 75% of the time intervals. If not, he is classified as Intermediate.

Table 11-4. SAMPLE SIZE FOR VARIABLES EXAMINED

Variable	Number of children born into sample
Children Available*	671
Physical growth	
At birth	405
At 6 months	447
Mental development	
At birth	157
At 6 months	472
Infant mortality (first 12 months of age)	653†
Birth interval (post-partum amenorrhea and lactation; entirely prospective and followed during entire interval)	334‡

*Births which occurred in the four villages from January 1, 1969 through February 28, 1973.
†Up to February 28, 1974.
‡Up to November 30, 1974.

Table 11-5. BIRTH WEIGHT BY THREE CATEGORIES OF MATERNAL CALORIC SUPPLEMENTATION DURING PREGNANCY

	Level of maternal caloric supplementation			
	Low	Intermediate	High	t test (high–low)
Mean birth weight (g)	2986	3036	3120	2.62*
Percent low birthweight (≤2.5 kg)	18.30	15.85	9.41	2.33†
Number of infants	153	82	170	

*$P \leq 0.01$.
†$P \leq 0.05$; t test, after arc sine transformation of percentage values.

Table 11-6. RELATIONSHIP BETWEEN DIFFERENCES IN CALORIC SUPPLEMENTATION DURING PREGNANCY AND DIFFERENCES IN BIRTH WEIGHT FOR TWO CONSECUTIVE SIBLINGS (LATTER MINUS PRECEDING PREGNANCY)

Differences in caloric supplementation categories	Difference in birth weights (mean ± SD) (g)	No. of sibling pairs
−40,000 – 0 cal	−172 ± 586	25
100 – 20,000 cal	20 ± 469	35
20,100 – 120,000 cal	218 ± 355	34

t Test (high–low) = 2.95; $P < .01$.

clear results. Although it has been demonstrated that maternal size before pregnancy and weight gain during pregnancy show consistent associations with birth weight, and that these relationships may reflect the influence of the maternal nutrition status on fetal growth (49), several studies using information from dietary surveys or food supplementation programs have failed to find an association between nutrient intake during pregnancy and birth weight (20, 48, 56). On the other hand, in studies showing an association between maternal nutritional intake and birth weight (7, 22, 41, 46), the influence of potentially confounding variables such as size of the mother, presence of infectious disease, and physical activity has not been explicitly controlled.

In the INCAP study, we found a consistently high association between maternal nutrition during pregnancy and birth weight (37, 38, 42, 43).

Table 11–5 shows the mean birth weight and percentage of low-birth-weight babies (≤ 2.5 kg) by three categories of maternal supplement ingestion. The low-caloric group consists of mothers whose total ingestion during pregnancy was less than 10,000 calories, while the high-calorie group consists of mothers whose ingestion was greater than or equal to 20,000 calories. The proportion of low-birth-weight babies was consistently lower in the better supplemented group in both fresco- and atole-consuming populations. Thus, the risk of delivering low-birth-weight babies among high supplemented mothers was roughly half that of the low supplemented group. However, since home caloric intake was similar in both groups, we have concluded that the supplemental calories were additional to the basic maternal diet. In the high-calorie supplementation group, this addition amounted to about 35,000 calories during all of pregnancy, or about 125 cal/day extra.

The possibility that confounding factors could be responsible for the association observed between caloric supplementation and birth weight was studied. Findings indicate that this association is not explained by other maternal variables related to birth weight such as size, home diet, morbidity, obstetrical characteristics, and socioeconomic status. Furthermore, the association between caloric supplementation and birth weight was not produced by undetected confounding factors related to the mother (*i.e.*, a tendency to have bigger babies), since it was also observed within two consecutive siblings of the same mother.

Table 11–6 points out the differences in birth weight for 94 pairs of siblings divided into three supplementation groups.

These groups were defined by differences in caloric supplementation of the mother between two successive pregnancies. When caloric supplementation during the latter pregnancy was lower than during the preceding pregnancy, the birth weight of the latter baby was also lower than the birth weight of the preceding baby. When the caloric supplementation during the latter pregnancy was higher than that during the preceding pregnancy, the latter newborn was heavier than the preceding one. The intermediate group is composed of siblings in which the increment in caloric supplementation during the latter pregnancy was between 100 and 20,000 calories. The difference in birth weight between both babies is close to zero and, therefore, intermediate between the extreme groups.

In summary: When a mother in our sample consumed more in one pregnancy than in another, there was a significant tendency for the baby of that pregnancy to be heavier at birth. We therefore conclude that caloric supplementation during pregnancy caused the observed decrease of the proportion of small babies in our study population.

EFFECT OF MATERNAL NUTRITION ON INFANT GROWTH

Maternal malnutrition during pregnancy and lactation has been implicated as one of several environmental factors contributing to postnatal growth retardation. Maternal nutrition is associated with the output of breast milk during lactation (2, 23, 26, 32, 46, 52, 58), which in turn is an important determinant of early postnatal growth in breast-fed infants (2, 24, 29, 31). This observation led us to postulate a causal relationship between maternal nutrition and the infant's physical growth. However, the design and data analyses of most of the published reports do not allow for assessment of a causal relationship between maternal nutrition and infant growth. Data from the INCAP study supports the hypothesis of a causal relationship between maternal nutrition and infant growth (35, 39, 40).

Table 11–7 shows the mean attained growth in weight and height to 6 months of age for each of three categories of cumulative maternal caloric supplementation since conception. Also included in this table are the *t* and *P* values for the differences between high and low supplementation groups. The existence of a consistent trend for children in the high category to be heavier and taller than children in the low category is apparent in these data.

The associations found between food supplementation and infant growth could, however, be due to factors other than supplementation. Such possible confounding factors must be excluded to claim a nutritional effect. For example, the mothers and children who attended the supplementation centers may have had better home diets or were healthier than subjects who did not attend the centers. However, analyses indicate that the association found between supplemented calories and infant growth is not explained by maternal and infant diet, family socioeconomic status, maternal and child morbidity, gestational age, or maternal anthropometric and obstetric characteristics.

The possibility also exists that sample mothers with heavier babies were those who tended to collaborate with the program. If this were the case, the observed association between caloric supplementation and growth would be artifactual. To explore the possibility that some constant maternal factor might be responsible for both the high consumption of food supplement and better growth, we again studied consecutive siblings of the same mother. Table 11–8 indicates the difference in weight for 111 pairs of siblings divided into three groups according to the differences between both siblings.

It is evident that there is an association between differences in cumulative

Table 11-7 ATTAINED WEIGHT AND HEIGHT FOR THREE CATEGORIES OF CUMULATIVE CALORIC SUPPLEMENTATION SINCE CONCEPTION

Age (mos)		Weight (kg) Low	Intermediate	High	*t* Test (low–high)	Height (cm) Low	Intermediate	High	*t* Test (high–low)
3	Mean	5.21	5.29	5.41	2.46*	56.5	56.6	57.4	3.14*
	N	155	168	105		155	169	105	
6	Mean	6.58	6.61	6.81	1.99†	62.1	62.1	62.7	1.92
	N	133	217	97		134	217	96	

*$P < 0.01$.
†$P < 0.05$.

Table 11-8. RELATIONSHIP BETWEEN DIFFERENCES IN CUMULATIVE MATERNAL CALORIC SUPPLEMENTATION SINCE CONCEPTION AND DIFFERENCES IN ATTAINED WEIGHT AT 6 MONTHS OF AGE FOR TWO CONSECUTIVE SIBLINGS (LATTER MINUS PRECEDING CHILD)

Differences in caloric supplementation	Differences in infant weight (mean ± SD) (g)	N
−40,000 – 0 cal	−247 ± 788	39
100 – 20,000 cal	−107 ± 861	34
20,100 – 120,000 cal	280 ± 920	38

t Test (high–low) ≈ 2.70; $P < .01$.

caloric supplementation of the pregnant and lactating mother up to 6 months after birth and differences in attained weight between siblings. Similar results have been found with attained height and with increments in weight and height from 0 to 6 months of age. The most suitable interpretation of these results is that food supplementation of both the pregnant and lactating mother caused an improvement of the infant's growth up to 6 months of age.

EFFECT OF MATERNAL NUTRITION ON MENTAL DEVELOPMENT

BIRTH WEIGHT AND MENTAL DEVELOPMENT

It has been reported that low birth weight is associated with deficits in mental performance (5, 8). Although many published studies ignore potentially confounding factors, those that have considered such variables support the conclusion that there is an association between low birth weight and poor mental performance (13–15, 21, 51, 53, 59, 60). Recently, we presented data which supports the conclusion that birth weight and psychomotor performance during the first months of life are associated (36).

Our sample includes 405 live newborns with birth weight data. Some of these newborns were tested by the Brazelton Assessment Scale within the first 2 weeks of life. This scale consists of 44 items which assess arousal state, irritability, motor capabilities, reaction to external stimuli, and neonatal reflexes. These 44 items were grouped into 11 summary variables of which the four with significant test–retest reliability have been analyzed. The Composite Infant Scale (CIS) was administered at 6 months of age and consisted of 91 items drawn from four widely used scales assessing psychomotor development in infancy, the Bayley, Catell, Merrill-Palmer, and Gesell scales. The 91 items comprising the scale were grouped into two subscales, mental and motor, each of which has test–retest reliability above .88.

Table 11–9 shows the correlation coefficients between birth weight and performance on the Brazelton and CIS Scales.

Birth weight is clearly associated with performance on three of the four Brazelton variables: habituation, motor fitness, and tremors and startles. The correlation between birth weight and the motor subscale of the CIS was also significant. Furthermore, the associations between birth weight and the other performance variables, although nonsignificant, were in the expected direction.

To examine alternative explanations, we measured approximately 50 factors which could be confounding or causal factors in the observed associations between birth weight and performance. After controlling for each of these variables, the association between birth weight and CIS motor performance remained significant.

We also explored differences between siblings in order to determine whether the relationship between birth weight and psychomotor performance was due to differences between mothers related to both birth weight and performance of their infants. In our sample we have 65 pairs of consecutive siblings on whom we have both birth weight and 6 months CIS data. The significant relationship observed in the entire sample between birth weight and performance on the motor subscale was replicated with this sibling sample ($r = .266$, $P < .05$). Therefore, the association between birth weight and psychomotor performance is consistent in the whole population and between siblings.

A reasonable interpretation of these results is that birth weight is related to psychomotor development during the first half year of life in these villages.

CALORIC SUPPLEMENTATION AND MENTAL DEVELOPMENT

Available data on psychologic test performance are sufficient to address the question of the relationship between food supplementation and infant psychologic test performance from birth to 6 months of age (34, 35). The association

Table 11–9. ASSOCIATION OF PSYCHOLOGIC TEST PERFORMANCE WITH BIRTH WEIGHT

Brazelton variables				CIS	
Motor fitness (N = 144)	Tremors & startles (N = 145)	Habituation (N = 141)	Alertness (N = 145)	Mental (N = 352)	Motor (N = 352)
0.28*	0.17†	0.27*	0.12	0.10	0.16*

*$P < 0.01$.
†$P < 0.05$.

between infant mental test performance and supplement ingestion is presented in Table 11–10.

Turning first to the results of evaluation of the infant shortly after birth, we note that although food supplementation during gestation was associated with higher birth weight, performance on the Brazelton Neonatal Evaluation Scale was not affected. The two Brazelton variables reported here are derived from clusters of items that appeared together in factor analyses of all test items. BB1 includes the negative signs of tonus, motor maturity, vigor, pull to sit, visual following, trembling, and interest in the examiner. BG1 is to some degree the

Table 11–10. PSYCHOLOGIC TEST PERFORMANCE BY THREE CATEGORIES OF CUMULATIVE MATERNAL CALORIC SUPPLEMENTATION DURING PREGNANCY AND LACTATION

Psychologic test score		Level of maternal caloric supplementation			
		Low	Intermediate	High	F
Brazelton Neonatal Assessment					
BB1	Mean	39.69	40.00	39.54	0.02
	N	42	32	83	
BG1	Mean	38.83	36.00	39.05	0.66
	N	42	32	83	
Composite Infant Scale (6 mos)					
Mental scale	Mean	73.8	76.3	77.8	2.87*
	N	150	221	101	
Motor scale	Mean	70.0	70.6	72.7	1.13
	N	150	221	101	

*$P < 0.05$.

Table 11–11. ASSOCIATION OF PSYCHOLOGIC TEST PERFORMANCE WITH SUPPLEMENT INGESTION

Test	I. Supplement ingested during pregnancy	II. Total supplement ingested to time of testing	III. Total Supplement ingested to time of testing (II). Controlling for supplement ingested during pregnancy (I)	IV. Supplement ingested during pregnancy (I). Controlling for postnatal supplement ingested to time of testing (II)
Boys				
Composite Infant Scale (6 mos) mental scale	.11	.04	−.07	.13*
Girls				
Composite Infant Scale (6 mos) mental scale	.13*	.01	−.018	.15*

*$P < 0.05$.
†$P < 0.01$.

opposite of BB1; it includes the positive signs of vigor, visual following, social interest in the examiner, and motor maturity.

Table 11–10 also reports results for the Composite Infant Scale at 6 months of age. At this age, only the mental scale is significantly associated with supplement ingestion.

There were relatively few sex differences with respect to the impact of food supplementation on psychologic test performance in this age range. In general, performances of boys and girls were comparable, and they responded similarly to food supplementation.

Table 11–11 presents data on the effects of the timing of supplement ingestion on psychologic test performance. Presented are correlations and partial correlations of Composite Infant Scale mental scores at 6 months with supplement ingestion. Not only are the correlations between gestational supplementation and test performance at 6 months of age significant, but once gestational supplementation is partialled out of the correlations between total cumulative supplementation and test score association, virtually no relationship remains between later cumulative supplementation and test performance. On the other hand, the effect of prenatal supplement and subsequent test performance is unaffected by controlling for later supplementation. Thus, as the previous analyses indicated, pregnancy is the crucial period for supplementation as far as the 6 months psychologic test performance is concerned.

The design of the present study, like those of many large-scale intervention studies, does not eliminate completely the possibility of confounding and subsequent misinterpretation of results. To avoid this possibility, we conducted a series of detailed analyses exploring various alternative interpretations of the results presented here. The first is the study of associations between supplement and psychologic test performance with the same mother from child to child. As in the case of birth weight and infant growth, these analyses show statistically significant relationships. In other words, even within the same family greater maternal supplement ingestion during one pregnancy is associated with superior test performance of that child.

EFFECT OF MATERNAL NUTRITION ON INFANT MORTALITY

Low birth weight is well established as an antecedent of excessive mortality in infants. Data from the United States (3, 9) and England (6) indicate that infant death rates rise dramatically among newborns weighing 2500 g or less. Developing countries present a high incidence of low-birth-weight babies, which have a higher risk of death (57) and are more susceptible to infectious diseases (47). Within our sample, infant mortality in babies of birth weight of 2.5 kg or less is nearly two times as much as that found in babies of birth weight greater than 2.5 kg (30, 39).

We have also found that infant mortality decreases as the level of maternal supplementation during pregnancy and lactation increases (Table 11–12).

Table 11–12 reports the association between caloric supplementation and

Table 11-12. INFANT MORTALITY BY THREE CATEGORIES OF CUMULATIVE MATERNAL CALORIC SUPPLEMENTATION DURING PREGNANCY AND LACTATION

	Level of cumulative maternal caloric supplementation		
	Low	Intermediate	High
Infant deaths	25	12	7
Number of infants	274	258	121
Infant death rate/1000	91.24	46.51	57.85

stillbirths and infant deaths during the first year of life. The proportion of deaths in the lower supplemented group was greater than in the intermediate and high groups. The magnitude of the difference is such that the risk of dying during the first year of life in the highly supplemented group is almost two thirds of that observed in the low supplemented group. These results indicate that child mortality decreases as the level of maternal supplementation increases.

EFFECT OF MATERNAL NUTRITION ON BIRTHSPACING

Several authors have postulated that malnutrition lowers the reproductive capacity of populations (12, 25, 27, 55). Some experimental evidence supports the plausibility of the above hypothesis. Chavez and Martinez (10), working with a small sample of Mexican women, report findings that suggest that one of the effects of supplementing the diet of pregnant and lactating women is to significantly reduce the duration of postpartum amenorrhea in nursing women. It was reported that mothers receiving food supplementation began menstruating at 7.5 months after delivery compared to control mothers, who began menstruating 14 months after giving birth.

The possibility that nutrition is related to fecundity is also given some support by the findings of Lev-Ran (44), who reported cases of secondary amenorrhea in young normal women following strict weight reduction diets. Similarly, the prevalence of amenorrhea has been reported to increase during times of severe food shortage and famine (1, 54).

Thus, differing lines of evidence suggest that nutrition may be an important determinant of human fecundity. While this proposition seems reasonable, there is at present a lack of direct empirical data to support it. One of the many areas explored in the longitudinal study has been the interrelationship between lactation, menstruation, and pregnancy (17–19). Since data have been collected prospectively (all the families are visited every 14 days), reliable information has been obtained in the areas of total birth interval, length of postpartum amenorrhea, length of menstruating interval, duration of lactation, outcome of the previous delivery, and survival of the last child born.

The median duration of lactation in the study communities is 18 months and of postpartum amenorrhea 14 months (means are 17 and 14 months, respectively). The two variables are highly associated, the correlation coefficient being 63 (334 cases, $P < .01$). In these analyses we have excluded cases of stillbirth or death in the first year of life. The median duration of postpartum amenorrhea in nursing women in our study is comparable to those reported in rural populations. Potter *et al.* (50), in a prospective study in India, reported a median of 11 months; Berman *et al.* (4), in a study on Eskimo women, reported a median of 10 months; and Chen *et al.* (12), in a study in Bangladesh reported a median of 13 months.

Data from the longitudinal study reveal a negative association between indicators of past and present nutritional status of the mother such as weight, height, head and arm circumference, and duration of postpartum amenorrhea, indicating that the better the nutritional status of the mother, the shorter the postpartum amenorrhea. A negative association was also found between home caloric intake and length of amenorrhea. Other variables, such as parity, previous birth interval, and age of the mother, were found to be positively correlated with duration of postpartum amenorrhea.

The longitudinal study data indicate a negative association between caloric supplementation ingested during pregnancy and duration of postpartum amenorrhea in both atole and fresco villages. However, in atole villages (where supplementation consisted of carbohydrates, proteins, and fat) this correlation is statistically significant ($r = -.199$, $P < .01$, $N = 171$), whereas in fresco villages (where supplementation consisted of carbohydrates only, in lesser concentrations than in atole villages) it is not. Significant differences in duration of postpartum amenorrhea between atole and fresco villages have not been found.

Another way of looking at these data consists of comparing the high-calorie and low-calorie supplemented groups within types of villages (atole versus fresco), as shown in Figure 11–1.

Two categories of supplementation were constructed: more than 20,000 calories during pregnancy, and 20,000 calories or less. Our data indicate that the high-calorie supplemented group in the atole villages had a significantly shorter duration of postpartum amenorrhea than the low-calorie supplemented group (t test, $P < .05$). Within fresco villages this difference, though in the expected direction, was not statistically significant. It should be noted that the reduction in the length of amenorrhea in the highly supplemented groups cannot be attributed to a reduction in the duration of lactation between the two groups. As shown in Figure 11–1, high and low supplemented groups exhibited virtually identical lactation intervals. These results indicate that in atole and in fresco villages the interval of lactation and menstruation (duration of lactation minus the length of postpartum amenorrhea) was longer in the high supplemented group than in the low supplemented group. This interval was positively associated with the amount of supplementation during pregnancy, significantly in atole villages ($P < .05$) and nonsignificantly in fresco villages. Furthermore, preliminary analyses showed that the amount of protein-calorie supplementation ingested by the mother during lactation was negatively associated not only with the duration of postpartum amenorrhea but also with the duration of the menstruating interval.

Table 11–13 shows the mean duration of lactation and postpartum amenorrhea for each of the three categories of cumulative caloric supplementation of sample pregnant and lactating mothers up to 6 months postpartum. Low and

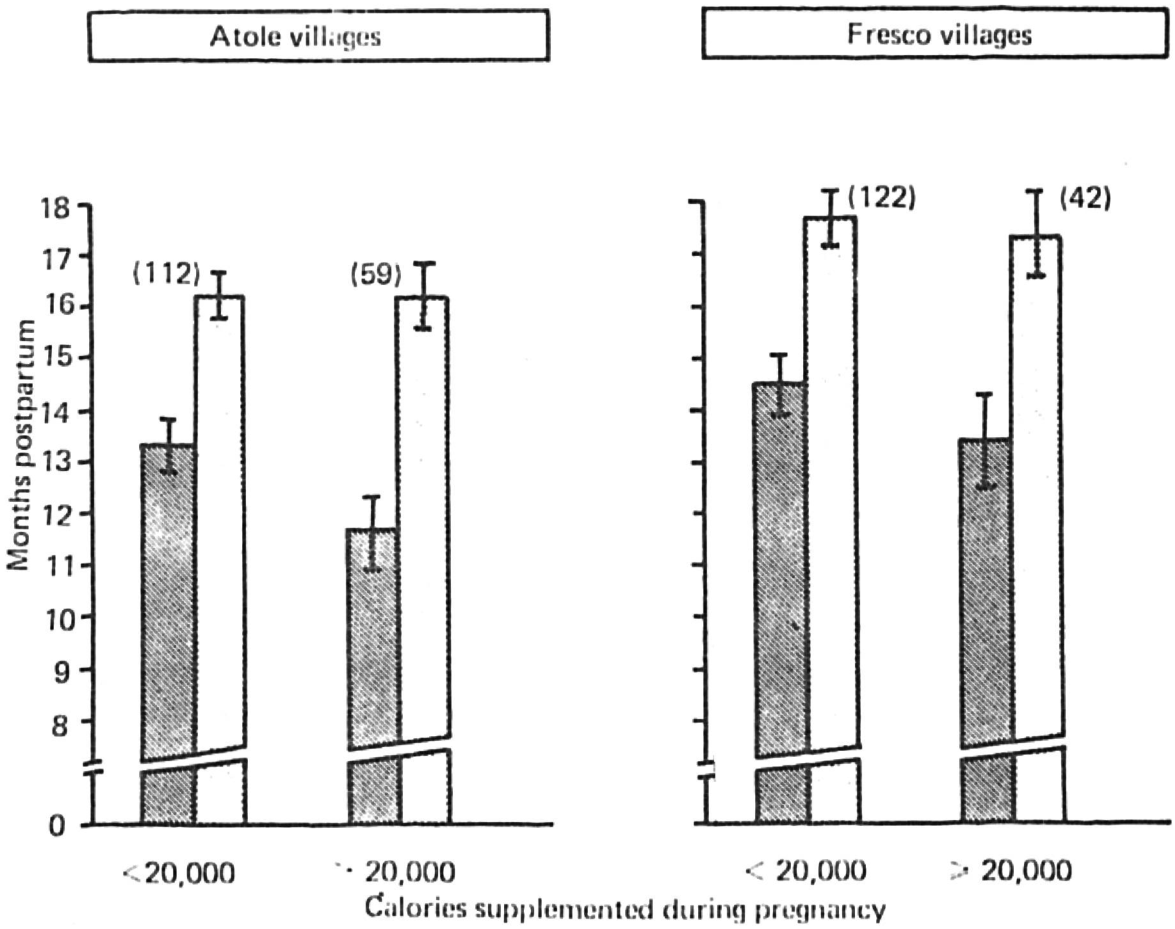

Fig. 11–1. Relationship between caloric supplementation during pregnancy and duration of postpartum amenorrhea *(hatched columns)* and lactation *(dotted columns)* in atole and fresco villages. The columns are of mean values, and the standard error is indicated by the vertical lines. Number of women studied is in parentheses.

Table 11–13. DURATION OF LACTATION AND POSTPARTUM AMENORRHEA

	Level of cumulative maternal caloric supplementation			
	Low	Intermediate	High	*t* Test (high–low)
Duration of lactation (mos)	18.40	17.98	17.61	1.15
Duration of postpartum amenorrhea (mos)	14.93	13.90	12.83	2.22*
Number of mothers	94	164	76	

*$P < 0.05$.

high supplemented groups showed nearly identical durations of lactation. On the other hand, the existence of a consistent trend for mothers in the intermediate and high supplementation categories to have a shorter postpartum amenorrhea than mothers in the low category is apparent in these data.

These results give partial support to the hypothesis that improvement of maternal nutrition is associated with a decrease in the duration of postpartum amenorrhea, and that this may increase the probability of a shorter birth interval. Though suggestive, these results suffer from weakness. No control was exerted over several possible sources of errors, including self-selection, cooperation, and frequency of sucking. Concerning the latter, it has been reported that the frequency of sucking and the amount of food supplemented to the infant during the first year of life may be important determinants of the duration of postpartum amenorrhea. It has also been suggested that food supplementation during lactation may diminish the sucking reflex and may also discourage lactation through a "substitution" effect, thereby shortening the period of postpartum amenorrhea (11).

The data presented suggest that poor nutrition and prolonged lactation lengthen the period of postpartum amenorrhea and, consequently, decrease reproductive capacity. Given that poor nutrition and prolonged lactation are characteristics of poor societies in developing nations, it is tempting to infer that fecundity and, consequently, fertility would be much higher in these areas were it not for these factors.

Despite the fact that poor nutritional status probably reduces the length of the infertile period following birth during which ovulation does not occur, it is difficult to estimate what the outcome of a nutrition program would be. It is easy of course to predict a population increase from the results presented and cited above. However, bettering nutritional status may in fact result in unchanged or lowered fecundity for the following reasons. Better maternal nutrition is associated with a longer period of lactation (17). Further, better nutrition may reduce infant mortality (39) and should, therefore, prolong lactation in cases where a death would have occurred. The increase in the length of lactation might then increase the length of the period of postpartum amenorrhea, compensating therefore the effect of nutrition per se on postpartum amenorrhea.

CONCLUSION

Information obtained from the published reports as well as from our own data leads us to believe that an improvement in the nutritional status of pregnant and lactating women is associated with a significant decrease in the prevalence of physical growth retardation up to 6 months of age and also of infant mortality. Nutrition also appears to be associated with psychologic test performance and birthspacing.

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