In: Nutrition and Fetal Development
M. Winick (Ed.), New York:
J. Wiley Sons Inc. 1974

7

DDH-#33

Relation of Maternal Supplementary Feeding During Pregnancy to Birth Weight and Other Sociobiological Factors

JEAN-PIERRE HABICHT, M.D.,
CHARLES YARBROUGH, PH.D.,
AARON LECHTIG, M. D., and
ROBERT E. KLEIN, PH.D.

Division of Human Development, Institute of Nutrition of Central America and Panama, Guatemala City, Guatemala

ABSTRACT. Supplementary feeding is offered to pregnant women in four rural Guatemalan villages. The mean birth weight of infants rises with maternal caloric ingestion during pregnancy. This positive association between maternal caloric ingestion from supplement and birth weight is observed whether the calories are ingested early or late in pregnancy.

The association between birth weight and maternal calorie supplementation during pregnancy is not due to confounding with maternal age, parity, interval since last birth, length of gestation, illnesses during pregnancy, indices of intrauterine infection, nor sex of the child.

Only maternal nutrition can explain the interrelationships of supplement ingestion and birth weight with home diet, socioeconomic status, and maternal size.

Contrary to expectations, protein ingestion from supplement had little, if any, additional effect on birth weight, a surprising finding since the home diet in these villages is kwashiorkorgenic for preschool children.

We present evidence, from studies in Guatemala, that improved nutrition during pregnancy can have an effect on the birth weight of the newborn in areas where chronic mild-to-moderate malnutrition is prevalent.

Our concern here is not with catastrophic acute-starvation situations, where the evidence for a marked effect of maternal nutrition on birth weight is clear (1, 2). Rather we are concerned about the much greater proportion of mothers with mild-to-moderate malnutrition.

A relationship between chronic maternal malnutrition during pregnancy and the weight of the newborn would seem self-evident to most of us, but to date no study in the published literature provides clear support for this contention. Indeed, some investigators have argued that the buffering capacity of the mother provides sufficient protection to the fetus, so that even under conditions of chronic maternal malnutrition fetal development is not adversely affected by the mother's suboptimal nutritional status (3, 4).

There are three reasons why the findings of these previous studies may not hold generally. The first is possible imprecision in the estimate of the nutritional intake of the mother. When the variability in measured intake of a given woman is not small relative to the differences in intake *among* all women, it may be difficult to find any association between maternal diet and birth weight, even if one exists. This inadequate level of precision in dietary measurement can occur not only when the dietary-survey method is inadequate but also when there is an insufficient range of nutrient intake among the women in the sample. A narrow range in nutrient intake among pregnant women would produce only a small change in birth weight—a change that might not be identifiable among other causes of birth-weight variation.

The second difficulty is that the nutritional status of the mother *before* pregnancy may affect birth weight. Nutrient supply can come to the fetus not only via the mother's digestive tract but also from maternal reserves when they are available and needed. These maternal reserves could compensate for substantial differences in nutrient intake during pregnancy. Indeed, we show evidence from our study that calories ingested early in pregnancy are stored and used as efficiently for the subsequent fetal growth as are calories ingested during the period of maximum fetal growth. Similar mechanisms of storage and subsequent use of caloric reserves may also hold true for calories ingested before conception.

The third consideration is the possibility of a threshold effect in maternal nutrition. In other words, above a certain level, maternal nutrient ingestion may have *no* effect on birth weight. If this is so, a study of fetal growth among well-nourished women would reveal no association between maternal diet during pregnancy and fetal birth weight.

Thus, in summary, we would expect to find an association between nutrient intake during pregnancy and birth weight only in a population displaying some evidence of malnutrition and only if there is sufficient variability in maternal nutrition that can be reliably measured.

On the other hand, among those studies that do report an association between maternal nutrition and birth weight, none has adequately controlled for important nonnutritional factors that might complicate this relationship. For example, mother's height and parity are known to affect birth weight (5). Moreover, these variables themselves probably vary with socioeconomic class and thus with maternal nutritional status.

In those intervention studies, where mothers are randomly selected for a supplementary feeding program, confounding of such nonnutritional factors is less likely to occur. Several such studies are now in progress in different parts of the world, but final results are not yet available.

An additional factor that may, however, confound such supplementation studies is medical care. Occasionally the supplemented group benefits from improved sanitation and medical care, whereas the nonsupplemented group does not. The importance of uniform medical care and environmental hygiene in these investigations is illustrated by the following findings.

Intrauterine infection, as measured by cord IgM level, is 10 times more frequent among the Latin American poor than among the poor in the United States or among the Latin American well-to-do (6). Since, in our study villages, newborns with high antitoxoplasmosis immunoglobulin M (IgM) levels generally weigh about 100 g less than newborns with low antitoxoplasmosis IgM levels, it is obvious that a nutritional explanation for birth-weight differences should not be invoked unless both supplemented and unsupplemented groups are similar in terms of environmental sanitation and medical care.

Finally, some supplementation studies have compared mothers who voluntarily cooperated in the supplementation program with mothers who did not. This design presents many of the problems discussed earlier since without random assignment to experimental groups the confounding factors affecting birth weight are difficult to control.

The data presented here are derived from a study in which much of the evidence is based on comparisons among groups of women with varying levels of voluntary cooperation with a food-supplementation program. Because of this experimental design we are not content to immediately interpret as causal the positive association found between food supplementation during pregnancy and subsequent birth weight

Table 1 Nutrient Content per Cup[a]

Nutrient	"Atole"	"Fresco"
Total calories	163	59
Protein (g)	11.46	—
Fat (g)	0.74	—
Carbohydrate (g)	27.77	15.30
Ascorbic acid (g)	4.00	4.00
Calcium (g)	0.37	—
Phosphorus (g)	0.31	—
Thiamine (mg)	1.14	1.10
Riboflavin (mg)	1.50	1.50
Niacin (mg)	18.50	18.50
Vitamin A (mg)	1.20	1.20
Iron (mg)	5.40	5.00
Fluoride (F mg equivalents)	0.20	0.20

[a] Each cup contained 180 ml.

of the infant. Nonnutritional alternative explanations must be eliminated to corroborate that birth weight is affected by maternal nutrition.

POPULATIONS STUDIED AND METHODS

We provide two types of supplement to four Guatemalan Ladino villages. In two of the villages we serve a high-protein supplement, *atole**; in the other two villages we serve a low-calorie supplement, *fresco*†. The chemical composition of these supplements is given in Table 1.

Attendance at the supplementation centers is voluntary, and the amount of supplement ingested during each visit is recorded to the nearest centiliter.

The composition of these supplements has been constant for calories, proteins, fat, carbohydrates, calcium and phosphorus since the inception of the program in 1969. The other nutrients (e.g., thiamine, riboflavin, niacin, ascorbic acid, vitamin A, iron, and fluoride) were added in 1971 to ensure that the only nutrients that could be limiting in supplemented mothers would be protein or

*The name of a gruel commonly made with corn.
†Spanish for refreshing, cool drink.

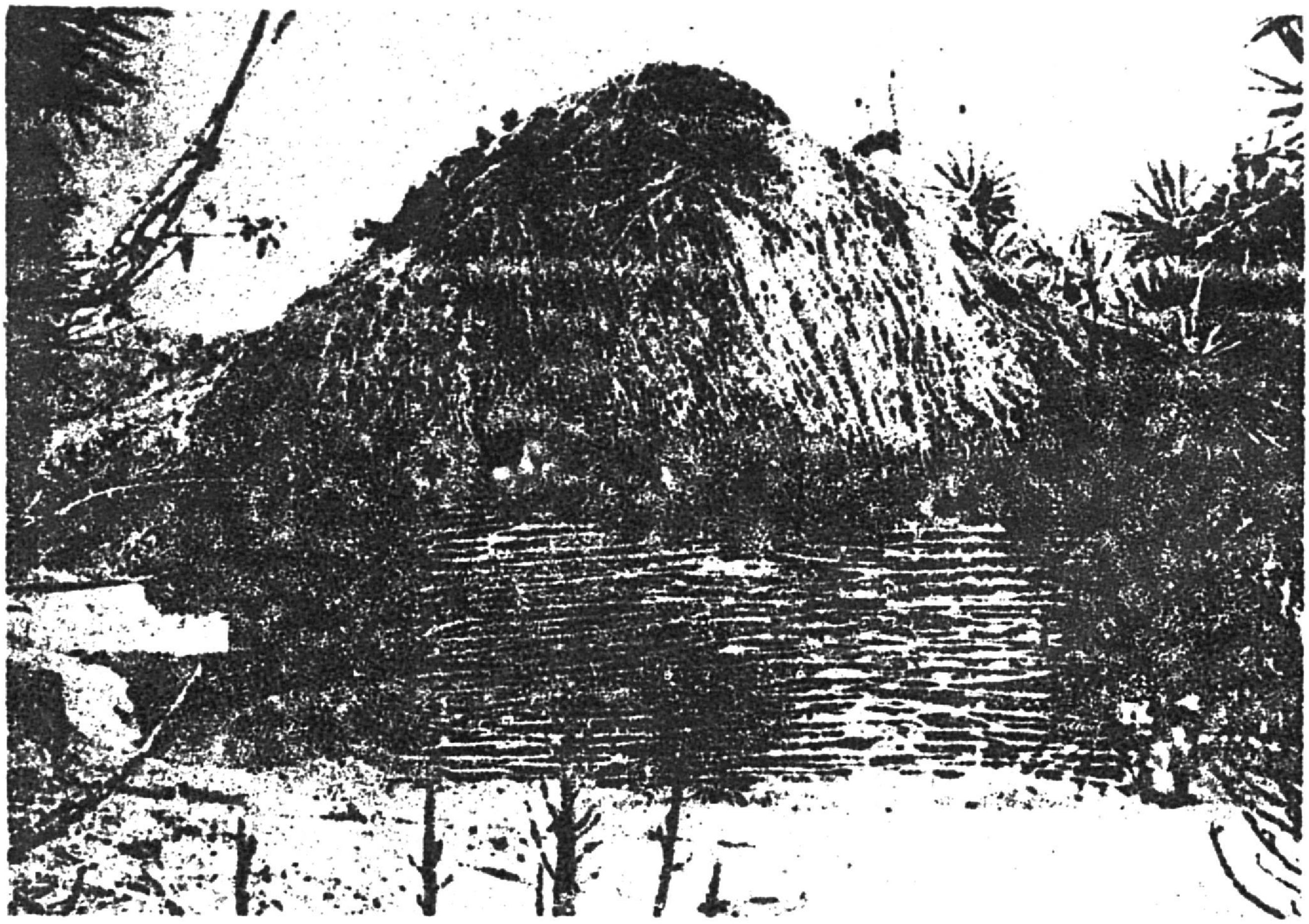

Fig. 1. A typical house in one of the Guatemalan study villages.

calories. No difference in birth weight has been found to be associated with the addition of nutrients in 1971.

The study villages are miserably poor, with a total median income in cash and produce (converted to American purchasing power) of $200 per family per year. The typical house is shown in Fig. 1. It is built of sticks and straw, and provides inadequate protection against the wind and rain. The floor is dirt, and with chickens, pigs, and dogs running in and out of the house, it is impossible to keep clean. Since few homes have sanitary facilities, the housewife also has to contend with human and animal excreta being tracked into the house.

Figure 2 shows a typical kitchen. It is a little more than an elevated mud hearth in the corner of the house. Many of these houses have no tables, and food is stored on the floor.

A frightening reflection of the misery that this poverty entails is that one child in seven used to die before reaching the age of 1 year compared with less than one in 45 in the United States. Clinical protein-deficiency disease in children, kwashiorkor, used to be prevalent, and children who do not attend the *atole* centers ingest inadequate protein to grow properly. As far as mothers are concerned,

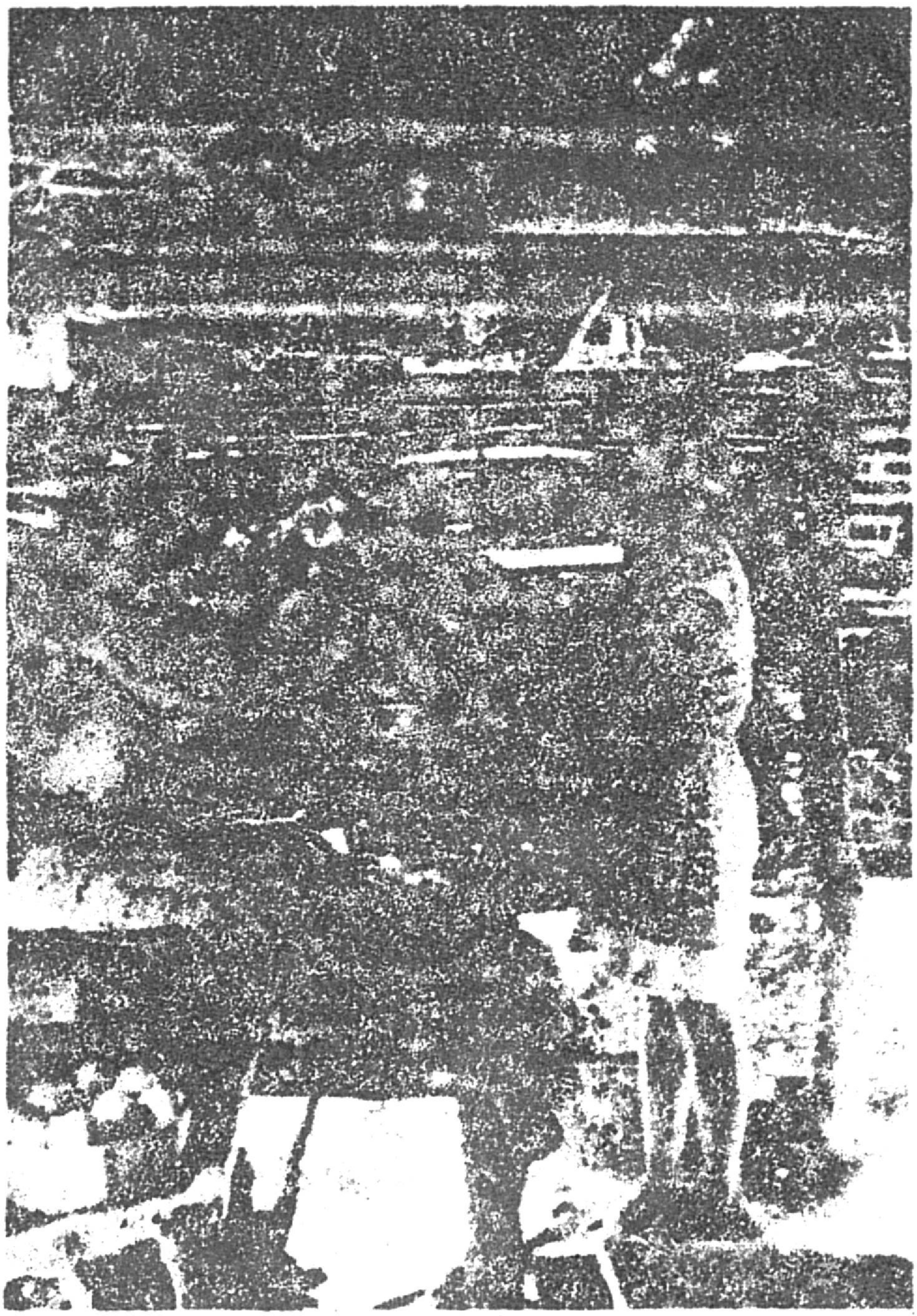

Fig. 2. Typical cooking facilities in one of the Guatemalan study villages.

dietary surveys during pregnancy indicate that during the last two trimesters the mothers have an average daily consumption of about 1500 ± 450 calories, and a protein intake of 42 ± 12 g. These figures are similar to those found elsewhere in Latin America (7), although they appear suspiciously low compared with recorded intakes from developed countries (3) and physiological requirements. Nevertheless, inadequate maternal nutrition was eloquently reflected in an average weight gain of about one-half (6.8 kg) of that observed for pregnant women in developed countries.

Birth weight is recorded within 24 hours of birth to the nearest 20 g. The data for one child, who weighed 5.5 kg at birth and whose mother had consumed 700 *fresco* calories during pregnancy, were discarded because inspection of birth-weight distribution revealed that a birth weight of 5.5 kg would be an exceptional outlier in this study population.

Onset of pregnancy is estimated for most mothers by the missing of a menstrual period. Since all mothers with preschool children are visited every 2 weeks, this information is elicited within 15 days of the missed period. Primiparas and those women with postpartum amenorrhea who become pregnant are usually identified somewhat later. In the analyses to be presented we shall use only the data from full-term infants (37 to 42 completed weeks of gestation) whose mothers had reliably known dates for cessation of menses and for whom we have a birth weight. This represents 288 of a total of 423 live births occurring between the end of 1968 and the end of May 1972. Twins occurred in 8 (four pairs) of 318 births studied, and 13 premature infants were born in the group of 310 women for whom the onset of amenorrhea was known. The data from the twin and premature births are not included in the analyses presented here.

Parity was determined by interview with the mother and review of the village civil registry. Dietary surveys are done at each trimester by recall, and at that time weight is measured on a beam scale to the nearest 100 g, and standing height is measured to the nearest 5 mm. Illness is estimated during the same fortnightly interviews that monitor menstruation.

The numbers in the tables and figures to be presented fluctuate because some measurements were instituted at different times and because we occasionally miss a measurement. We thus present birth weight in all analyses to show that these variations in sampling do not affect the association of birth weight and ingestion of supplement calories during pregnancy.

RESULTS

Figure 3 shows that women who ingest increasing amounts of calories from the food supplements have on the average increasingly larger babies.

The caloric limits defining the three groups (< 5000 calories; 5000 to 19,999 calories; > 20,000 calories during the whole of pregnancy) in Fig. 3 were chosen on the following basis: less than 5000 calories is so small that we would expect no nutritional effect on birth weight; at the other extreme, birth weight increases little above the 20,000 to 40,000 caloric range.

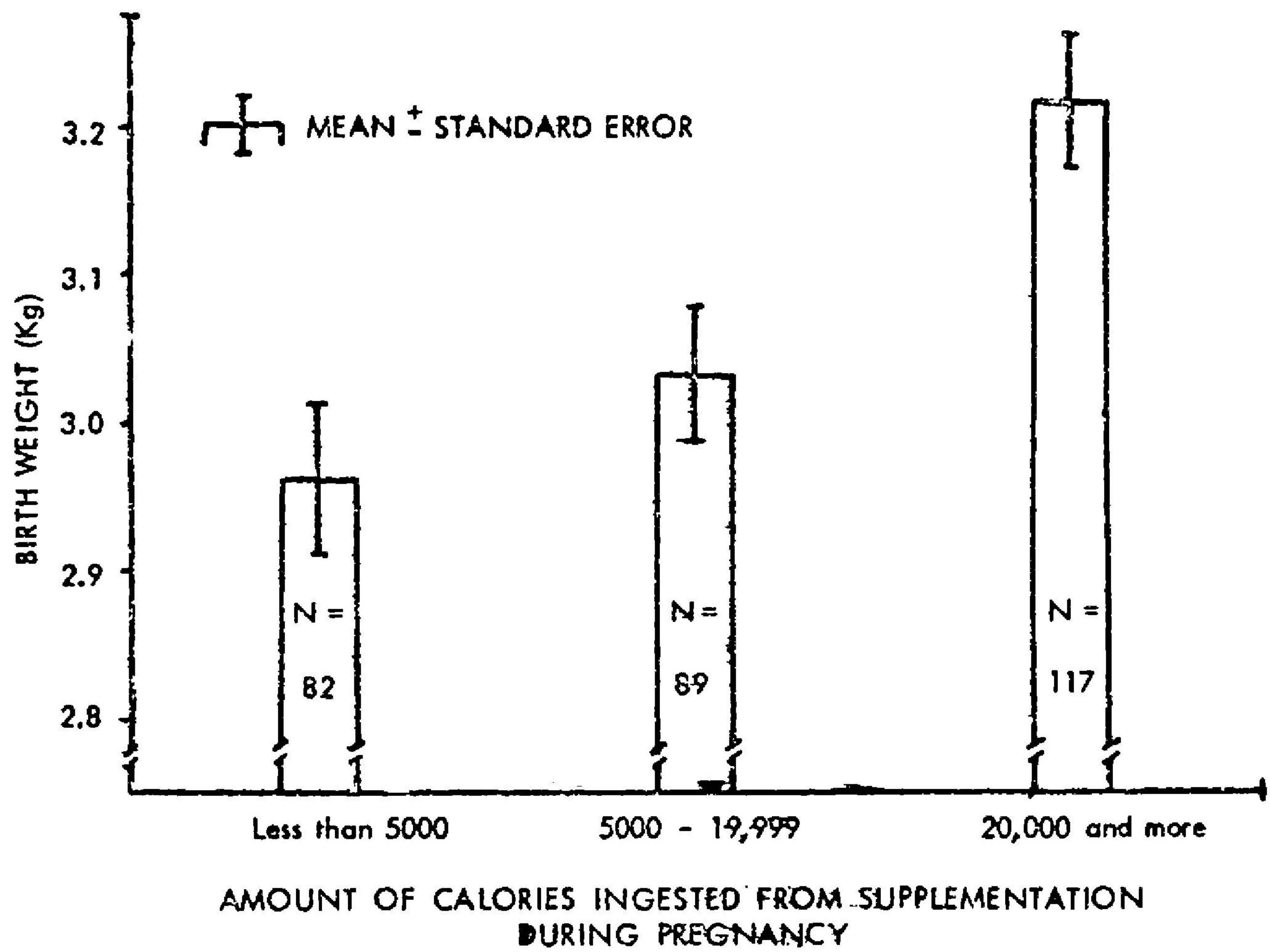

Fig. 3. Association between birth weight and caloric supplementation during pregnancy.

DISCUSSION

The increase in mean birth weight reflected in Fig. 3 is due to an overall increase along the entire continuum of birth weights for the sample. Table 2 shows that about 80% of the birth weights lie between 2.5 and 3.5 kg at all levels of maternal supplementation. However, of the 20% of birth weights lying outside this range, the majority are below 2.5 kg in the low-calorie-ingestion group, while as one moves to the high-calorie-ingestion group, the majority of the 20% of outliers shifts to above 3.5 kg. Of the 69 births among women who ingested more than 31,000 calories, 19% are above 3.5 kg and none below 2.5 kg. This upward shift in birth-weight distribution implies that for each 10,000 calories of supplement ingested by the mother during pregnancy, the average newborn's birth weight increases 50 g. It is also of interest that in spite of an increase in the number of heavier babies, we have not found an increase in difficult labor among the mothers in the sample.

The decrease in the number of "small-for-date" babies (those

Table 2 Comparison of Caloric Ingestion from Maternal Supplementation with Birth-Weight Distribution

	< 5000 calories N = 82	5000–19,999 calories N = 89	> 20,000 calories N = 117
	Percent Birth-Weight Distribution		
Birth Weight (kg)			
> 3.5	7.3%	11.9%	20.9%
2.5–3.5	78.3%	81.0%	75.6%
< 2.5	13.4%	7.1%	3.5%
Total	100.0%	100.0%	100.0%

weighing less than 2.5 kg at term) is particularly important because mortality during the first year of life is four times greater for children under 2.5 kg than it is for heavier infants in the study villages. This fourfold increase in death rate for children under 2.5 kg does not appear to change as maternal calorie supplementation during pregnancy increases, but the proportion of small-for-date babies decreases. Thus the overall infant mortality falls, and this decline is mediated by the overall rise in birth weight associated with maternal supplementation during pregnancy (8).

In one of the food supplements, *atole*, a high-quality protein (9) accounts for 17.8% of the calories. The other supplement, *fresco*, has no protein. We had originally thought that the high-protein *atole* would have a greater effect on fetal growth than the *fresco* because we had supposed that the maternal home diet would be inadequate in proteins. This supposition was based on the knowledge that protein supplementation promotes better physical growth among preschool children in these villages, whereas calorie supplementation does not (10). However, comparing isocaloric amounts of supplementation during pregnancy (Fig. 4) for the high-protein *atole* and the protein-free *fresco* separately with the birth weight of the children reveals that protein added to the calories had little, if any, effect on birth weight. It thus seems clear that the first limiting nutrient in these women was calories. This is borne out in partial-regression analyses where supplement calories (C) explain three times more of the residual variance of birth weight (B) than do supplement proteins (P) (rBC.P = .119, $p < .05$; rBP.C = .066, p not significant, $N = 288$).

This association of maternal caloric supplementation with birth weight is, of course, closely associated with how well the pregnant

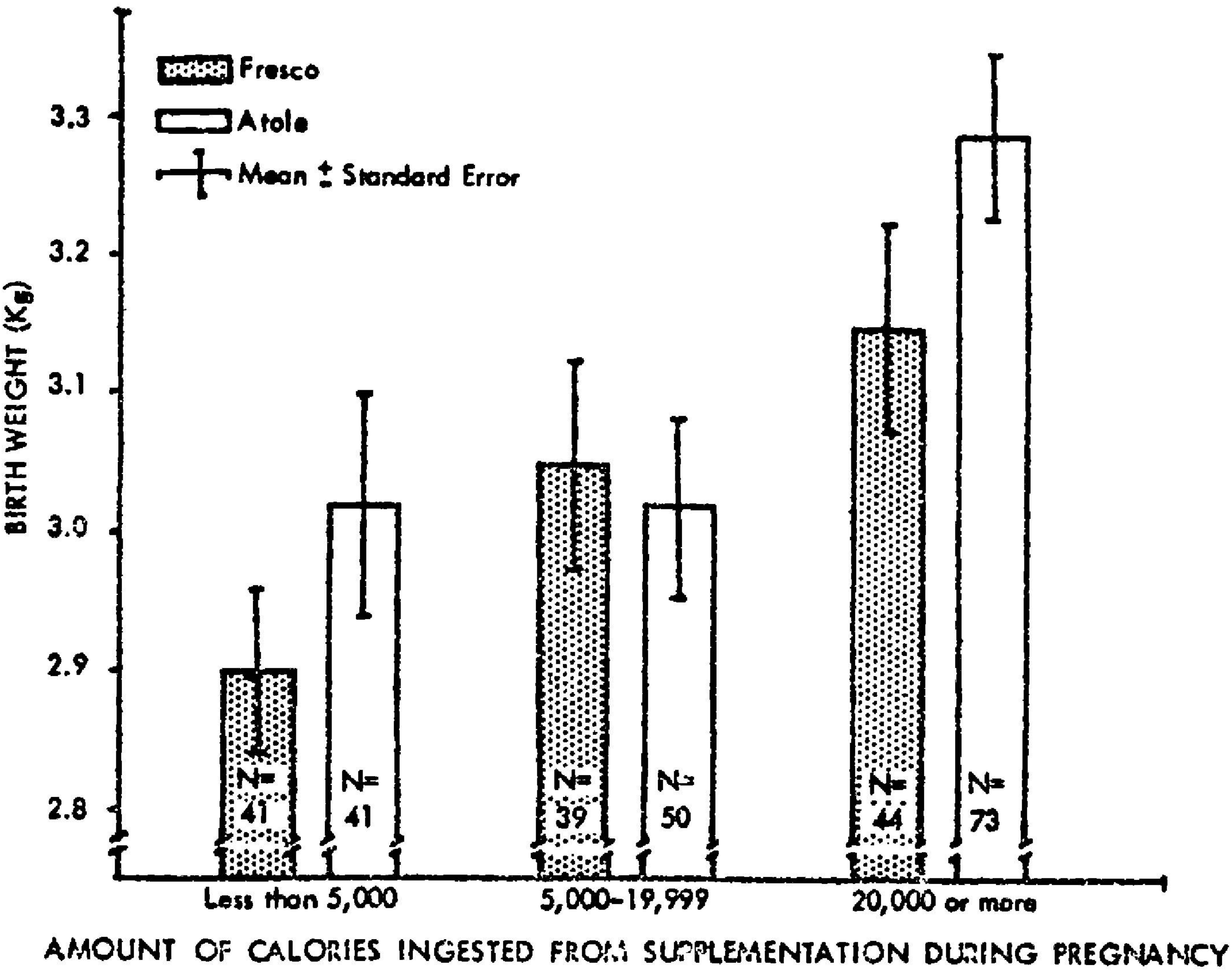

Fig. 4. Association between birth weight and caloric supplementation during pregnancy: comparison of *atole* and *fresco*.

women cooperate with the supplementary feeding program. There remains the possibility that nonnutritional factors associated with maternal cooperation might explain the association of birth weight with maternal supplementation. The following analyses investigate various such possibilities.

The most direct method of measuring cooperation in the supplementation program is to measure how often a mother attends the supplementation center. Mothers who come to the centers do not all ingest the same amount of calories. If the association between birth weight and calorie intake is due simply to factors associated with attending the supplementation centers, then the association with birth weight should be higher for days of attendance than for calorie ingestion.

Birth weight does *not*, in fact, increase with cooperation, as measured by days of attendance at the supplementation center when one holds constant the calorie intake from supplement. On the other hand, if one considers women who attend the supplementation centers equally well, increases in caloric intake are associated with increases in birth weight ($N = 288$) because partial correlation of calories (C) [given days of attendance (D)] with birth weight (B) is significant (rBC.D = .143, $p < .05$), whereas that for days attendance is not (rBD.C = −.037). Thus factors associated with cooperation as measured by days of attendance to the supplementation centers do not account for the observed association between birth weight and calories ingested from the supplement.

One can imagine, however, that there might be still other socioeconomic and physiologic factors that could affect ingestion, but not attendance, and also might affect birth weight. In the study villages both caloric ingestion and a socioeconomic index of home instruction increases with increasing birth weight. The index of home instruction reflects the amount of overt teaching family members address to their children. This index is significantly correlated with the mental performance and growth of preschool children (11) as it is with birth weight ($r = .240$, $N = 153$). On the other hand, both home caloric ingestion and the index of home instruction fall with increasing supplement calorie ingestion and the associated rise in birth weight. Hence neither home instruction nor home diet can explain the positive association between supplementation during pregnancy and birth weight. In fact, the nutritional mechanism of caloric supplementation explains best the negative relationship of home diet and socioeconomic indices with supplementation, in spite of the positive association all three of these factors have with birth weight. Thus families of lower socioeconomic status and lower home caloric ingestion supplement their diets sufficiently at the supplementation centers, so that their babies are larger than infants of unsupplemented mothers who are of a higher socioeconomic status and who eat more at home. Thus calorie consumption in the supplementation centers would more than compensate for the poor home diet of the mothers.

Another nonnutritional mechanism that might explain the association of birth weight with supplement ingestion is maternal illness. Maternal illnesses could lead to greater intrauterine infection rates, resulting in retarded fetal growth. If mothers who are ill come less frequently to the supplementation centers, this would explain why unsupplemented mothers have smaller babies. In fact, such is not the case. As Table 3 shows, maternal illness as measured by days ill with common symptoms such as fever, respiratory infections, or gastrointestinal and genitourinary afflictions occurred infrequently, and mothers'

Table 3 Comparison of Caloric Ingestion from Maternal Supplementation with Illness During Pregnancy and Birth Weight

	Calories Ingested from Supplementation During Pregnancy		
	< 5000 $N = 46$	5000–19,999 $N = 69$	> 20,000 $N = 88$
Birth weight (kg)	2.98 ± 0.48[a]	3.03 ± 0.48	3.25 ± 0.53
Illness per month (days)	0.37 ± 0.59[a]	0.51 ± 0.80	0.63 ± [illegible]

[a]Mean ± standard deviation.

Table 4 Comparison of Caloric Ingestion from Maternal Supplementation with High Cord IgM Levels and Birth Weight

	Calories Ingested from Supplementation During Pregnancy		
	< 5000 $N = 23$	5000–19,999 $N = 26$	> 20,000 $N = 53$
Birth weight (kg)	3.12 ± 0.37[a]	3.00 ± 0.29	3.24 ± 0.66
Cord IgM level (% > 20 μg/ml)	61	53	64

[a]Mean ± standard deviation.

illness rates tend to increase with supplementation, both possibly being related to decreasing socioeconomic status.

Furthermore, as Table 4 shows in a small subsample of newborns, the percentage of high cord IgM levels (> 20mg/ml), evidence of intrauterine infection, is not associated with maternal supplementation during pregnancy.

Another physiological but nonnutritional mechanism that could explain the association of birth weight with supplementation during pregnancy is suggested by Table 5, which reveals that the birth interval is shorter in the well-supplemented groups of mothers.

Mothers with short birth intervals are likely to have more babies. Possibly these multiparous mothers selectively come to the supplementation centers because they are nutritionally depleted from rapid childbearing. As birth weight increases with increasing parity ($r = .168$, $p < .05$), this could explain the greater birth weights in well-supplemented mothers. However, as Table 6 shows, neither

Table 5 Comparison of Calorie Ingestion from Maternal Supplementation with Interval Since Last Birth and Birth Weight

	Calories Ingested from Supplementation During Pregnancy		
	< 5000 $N = 61$	5000–19,999 $N = 68$	> 20,000 $N = 101$
Birth weight (kg)	3.03 ± 0.46[a]	3.04 ± 0.44	3.25 ± 0.52
Interval since last birth (months)	30.1 ± 13.5[a]	29.1 ± 15.5	26.7 ± 10.9

[a]Mean ± standard deviation.

Table 6 Comparison of Calorie Ingestion from Maternal Supplementation with Maternal Characteristics and Birth Weight

	Calories Ingested from Supplementation During Pregnancy		
	< 5000 $N = 75$	5000–19,999 $N = 87$	> 20,000 $N = 117$
Birth weight (kg)	2.98 ± 0.45[a]	3.01 ± 0.45	3.22 ± 0.50
Maternal characteristics:			
Height (cm)	149.8 ± 4.6[a]	148.5 ± 5.5	149.7 ± 5.2
Age (years)	26.9 ± 6.8[a]	28.3 ± 7.5	28.0 ± 7.1
Parity	3.7 ± 3.4[a]	3.8 ± 3.5	4.0 ± 3.1
Gestational age (months)	39.9 ± 1.3[a]	39.9 ± 1.1	39.6 ± 2.3

[a]Mean ± standard deviation.

parity nor maternal age can explain the increases in birth weight associated with maternal calorie supplementation.

It is also possible that maternal size could account for the supplementation–birth weight association. This might be the case if all women in the villages ate the same diet. Taller mothers would have a greater calorie deficit than short mothers and thus would tend to ingest more supplement. Mother's height influences birth weight independently of calorie consumption at the supplementation centers ($r = .183$, $N = 283$, $p < .05$).

However, mother's height cannot explain the relation between calorie ingestion and birth weight since, as Table 6 shows, there is in

Table 7 Comparison of Calorie Ingestion from Supplementation During Pregnancy with Birth Weight and Maternal Weight During First Trimester of Pregnancy

	Calories Ingested from Supplementation During Pregnancy		
	< 5000 $N = 25$	5000–19,999 $N = 44$	> 20,000 $N = 83$
Birth weight (kg)	3.06 ± 0.51[a]	3.10 ± 0.51	3.25 ± 0.53
Maternal weight in first trimester (kg)	48.9 ± 6.8[a]	47.6 ± 5.4	47.9 ± 6.5

[a]Mean ± standard deviation.

fact no increase in tall mothers across the different levels of supplementation. Further, as Table 7 shows, mothers in the three supplementation groups were not only of similar height but also of similar weight during the first trimester of pregnancy.

Thus the positive association between birth weight and mother's weight at the inception of pregnancy ($r = .305$, $N = 152$, $p < .01$) does not explain the association between maternal calorie supplementation and the subsequent birth weight of the child. In fact, the strong correlation between maternal weight during the first trimester of pregnancy and birth weight is yet another argument for the effect of maternal nutrition on the birth weight of the infant because it is consistent with the notion that mothers with greater calorie reserves have larger babies.

A final possible nonnutritional mechanism to explain our results could be maternal smoking, a strong determinant of birth weight in developed countries (12). It is not, however, a factor in the study villages because cigarette smoking among child bearing women is extremely rare.

We have so far explored nonnutritional mechanisms that would explain our finding that the birth weight of infants increased as maternal calorie supplementation increased during pregnancy. No such nonnutritional mechanism can explain this association between supplementation and birth weight. In fact, we have been led by the data to a nutritional explanation of this association. The first time by the negative association of home diet and socioeconomic indices with supplementation, indicating that those who most need supplementation are coming to the supplementation centers and that their babies are larger because of the supplement ingested. The second finding

Table 7 Comparison of Calorie Ingestion from Supplementation During Pregnancy with Birth Weight and Maternal Weight During First Trimester of Pregnancy

	Calories Ingested from Supplementation During Pregnancy		
	< 5000 $N = 25$	5000–19,999 $N = 44$	> 20,000 $N = 83$
Birth weight (kg)	3.06 ± 0.51[a]	3.10 ± 0.51	3.25 ± 0.53
Maternal weight in first trimester (kg)	48.9 ± 6.8[a]	47.6 ± 5.4	47.9 ± 6.5

[a]Mean ± standard deviation.

fact no increase in tall mothers across the different levels of supplementation. Further, as Table 7 shows, mothers in the three supplementation groups were not only of similar height but also of similar weight during the first trimester of pregnancy.

Thus the positive association between birth weight and mother's weight at the inception of pregnancy ($r = .305$, $N = 152$, $p < .01$) does not explain the association between maternal calorie supplementation and the subsequent birth weight of the child. In fact, the strong correlation between maternal weight during the first trimester of pregnancy and birth weight is yet another argument for the effect of maternal nutrition on the birth weight of the infant because it is consistent with the notion that mothers with greater calorie reserves have larger babies.

A final possible nonnutritional mechanism to explain our results could be maternal smoking, a strong determinant of birth weight in developed countries (12). It is not, however, a factor in the study villages because cigarette smoking among child bearing women is extremely rare.

We have so far explored nonnutritional mechanisms that would explain our finding that the birth weight of infants increased as maternal calorie supplementation increased during pregnancy. No such nonnutritional mechanism can explain this association between supplementation and birth weight. In fact, we have been led by the data to a nutritional explanation of this association. The first time by the negative association of home diet and socioeconomic indices with supplementation, indicating that those who most need supplementation are coming to the supplementation centers and that their babies are larger because of the supplement ingested. The second finding indicating a possible nutritional explanation for birth weight is the correlation between mother's weight during the first trimester and birth weight, suggesting that maternal calorie reserves are mobilized for fetal growth.

We have further direct evidence that caloric intake during pregnancy is a determinant of birth weight. There are so far nine women who had not partaken of the supplement during one pregnancy, but who consumed more than 20,000 supplemental calories during a second pregnancy. The increase in birth weight, adjusted for parity, was +0.40 kg. In comparison, for eight mothers who were not supplemented in either pregnancy the change in birth weight was −0.05 kg. Thus a significant ($p < .01$) increase in birth weight in favor of the second infant occurred only when the mother was supplemented during the second pregnancy (13).

A final possibility, biological in character, is that increased fetal growth increases maternal appetite dictated by fetal nutritional demands. Thus maternal appetite might be increased when the mother is carrying a fetus that will be ultimately larger. Because supplementation is available, she would come to our supplementation centers. It is conceivable that if the supplementation centers had not been there, the fetus would have grown just as large and that the mother would have increased her home caloric intake or sacrificed more of her own substance to meet the fetus's nutritional demands. Thus supplementation, while possibly a good thing for the mother, would not be the cause of increased fetal growth. This is a testable hypothesis. In all parts of the world boys have a higher mean birth weight than girls. In our villages this difference is 73 g. Therefore, we would expect to find that the mothers of male fetuses would consume more supplement than the mothers of female fetuses, if indeed the increased intrauterine growth of the boys provokes an increase in maternal appetite. As Table 8 shows, increased supplement intake is not associated with a substantial increase in boys' births. The argument that greater intrauterine growth is the cause and not the result of increased supplement ingestion is thus not substantiated.

We conclude that moderate maternal malnutrition does appear to have an adverse effect on the birth weight of the infant. We have tried to consider possible alternative explanations. In our study population we find no such hidden and competing explanation. Thus we believe that in the other investigations reporting no nutritional effect on birth weight either the mothers were not sufficiently malnourished and/or the methods were inadequate to identify sufficient variation in maternal nutrition to reflect differences in newborn birth weight.

Table 8 Comparison of Calorie Ingestion from Maternal Supplementation with Sex of the Infant and Birth Weight

	Calories Ingested from Supplementation During Pregnancy		
	< 5000 $N = 75$	5000–19,999 $N = 87$	> 20,000 $N = 117$
Birth weight (kg)	2.98 ± 0.45[a]	3.01 ± 0.45	3.22 ± 0.50
Sex (% male)	53[a]	53	56

[a] Mean ± standard deviation.

Table 9 Sample Size of Mothers by Timing and Amount of Supplement Ingestion

Total Supplement Calories Ingested During Pregnancy	Trimester in Which 75% of Supplement Was Consumed						
	1	2	1 + 2	1 + 3	2 + 3	1 + 2 + 3	3
> 20,000	1	1	24	11	62	11	7
		26			84		
< 20,000	18	4	16	8	47	20	58
		38			75		

Once we felt sure that caloric supplementation during pregnancy did increase birth weight in the Guatemalan villages studied, we next investigated the optimum timing of caloric supplementation. Our data suggest that the optimum time to begin supplementation is as early as possible in pregnancy and that supplementation should continue throughout pregnancy. This is surprising because fetal weight gain is greater during the last trimester of pregnancy. However, maternal gain among the mothers in this study was linear from the second through the eighth month of pregnancy.

Possibly calories are deposited as fat during the first trimester of pregnancy, and these calories are subsequently transferred to the fetus as his needs increase. This would be a smooth and efficient mechanism to ensure the fetus's nutritional needs without imposing radical increases in maternal food intake—precisely at the time when most women feel they already have enough in their abdomens.

Support for this hypothetical model can be found in our study. Table 9 presents data on mothers who consumed more than or less than 20,000 supplement calories during pregnancy. These mothers are compared on the basis of whether they ingested most (75%) of these calories during the first two trimesters, during the last trimester only, or in some combination of the first two trimesters and the third trimester.

The left-hand part of Fig. 5 shows again the improvement in birth weight of infants born to the 117 well-supplemented mothers (20,000 calories or more during pregnancy) compared with infants born to the poorly supplemented mothers (< 20,000 calories).

The right-hand section of Fig. 5 shows the differences between the mean birth weight of well-supplemented and poorly supplemented mothers who had ingested 75% of their supplementation calories in the first two trimesters of pregnancy, in some combination of all these trimesters, or in the last trimester only. The differences between well-supplemented and poorly supplemented mothers are similar regardless of when the well-supplemented mothers consumed most (75%) of their calories. This indicates that the conversion of supplement calories into newborn weight was equally efficient regardless of when the calories were ingested during pregnancy.

It must be emphasized that these findings apply to pregnant women whose home diets are apparently more inadequate in calories than in

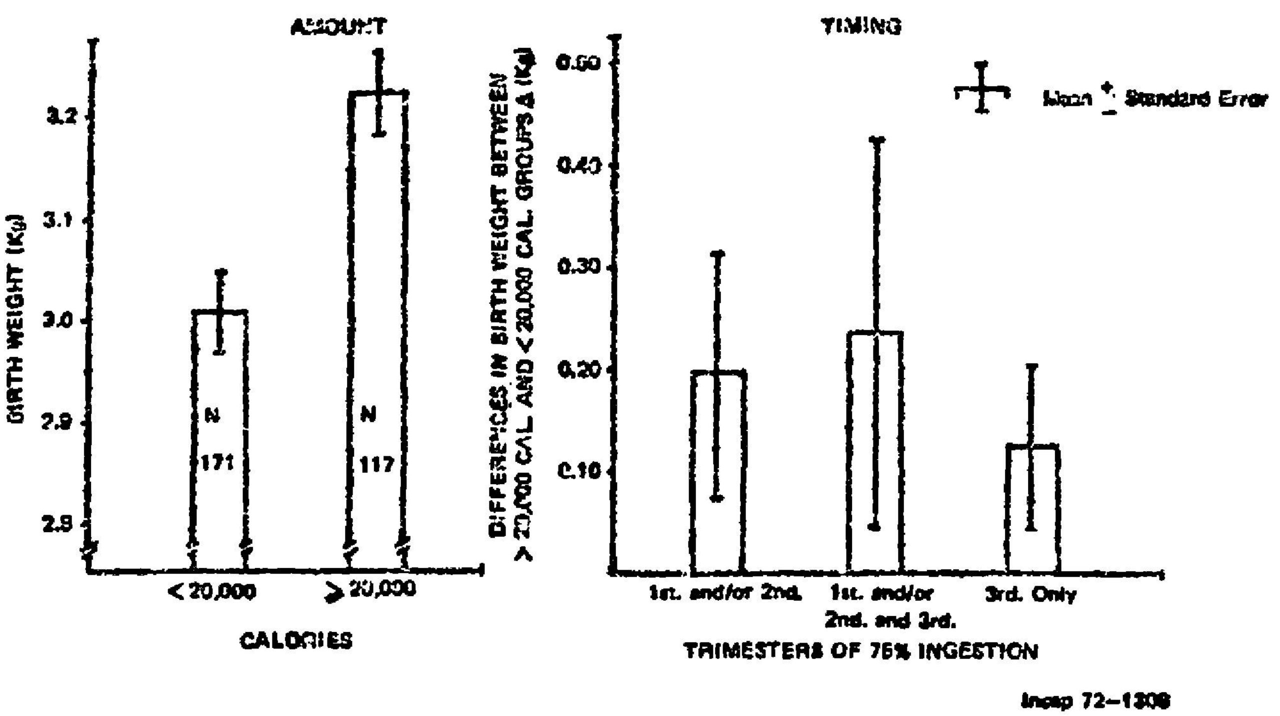

Fig. 5. Relation of amount and timing of maternal supplementation during pregnancy to birth weight.

proteins. In view of the fact that these home diets are kwashiorkorgenic for toddlers, it may be difficult to find populations in which the diet of pregnant women is limiting in proteins, as reflected by changes in birth weight after protein supplementation.

CONCLUSIONS AND SUMMARY

We have presented evidence that chronic limitation of calories during pregnancy is associated with lowered birth weight and an increase in small-for-date babies. For a supplementation program to be effective in preventing small-for-date babies under such circumstances, one should supplement the diets of pregnant women as early in pregnancy as possible because it is easier to consume 20,000 additional calories over two or three trimesters than over one. In fact, of the 288 pregnant women in this study, only nine managed to consume 20,000 calories in one trimester, whereas 108 consumed that much and more over the entire course of their pregnancy.

At present we have measured the effect of supplementation only in quantitative terms of baby weight. It remains to be seen whether more baby really means a better baby.

ACKNOWLEDGMENTS

The work described in this chapter would not have been possible without the administrative skills of our Field Director, Dr. Guillermo Guzmán. We are much indebted to Fryda de Díaz, M.S., who was responsible for the calculations, whether by computer or by hand. Finally, we thank Professor Angus Thomson of Newcastle upon Tyne for his interest and advice.

Our research was supported by a contract (PH43-65-640) from the National Institute of Child Health and Human Development, Bethesda, Maryland.

REFERENCES

1. A. N. Antonov, *J. Pediatr.* 30: 250 (1947).
2. C. A. Smith, *J. Pediatr.* 30: 229 (1947).
3. F. E. Hytten and I. Leitch, *The Physiology of Human Pregnancy*, 2nd ed. London: Blackwell, 1971, pp. 311–314 and 448–450.
4. A. Lechtig, G. Arroyave, J.-P. Habicht, and M. Béhar, *Arch. Latinoam. Nutr.* 21: 505 (1971).
5. A. M. Thomson, in *Perinatal Medicine*. Basel: Karger, 1971.
6. A. Lechtig, L. J. Mata, J.-P. Habicht, R. E. Klein, G. Guzmán, A. Cáceres, and C. Alford, in *Ecology of Food and Nutrition*. In press.

7. Pan American Health Organization, *Maternal Nutrition and Family Planning in the Americas.* Report of a PAHO Technical Group Meeting, Washington, D. C., October 20-24, 1969. Scientific Publication No. 204, pp. 8–9.

8. J.-P. Habicht, C. Yarbrough, R. E. Klein, and A. Lechtig, *Nutr. Rep. Internat.* 7: 533 (1973).

9. J. J. Erdmenger, L. G. Elías, N. de Souza, J. B. Salomon, R. Bressani, G. Arroyave, and J.-P. Habicht, *Arch. Latinoam. Nutr.* 22: 179 (1972).

10. J.-P. Habicht, J. A. Schwedes, G. Arroyave, and R. E. Klein, *Am. J. Clin. Nutr.* 26: 1046 (1973).

11. R. E. Klein, H. E. Freeman, J. Kagan, C. Yarbrough, and J.-P. Habicht, *J. Health Soc. Behav.* 13: 219 (1972).

12. N. R. Butler, H. Goldstein, and E. M. Ross, *Br. Med. J.* 2. 127 (1972).

13. A. Lechtig, J.-P. Habicht, C. Yarbrough, H. Delgado, G. Guzmán, and R. E. Klein, in *Proc. Nutr. Congr. IX, Mexico, 1972.* Vol. II. Basel: Karger, 1973. In press.