EFFECTS OF MATERNAL NUTRITION ON FETAL GROWTH AND INFANT DEVELOPMENT[1, 2]

R. E. Klein, P. Arenales, H. Delgado, P. L. Engle, G. Guzmán, M. Irwin, R. Lasky, A. Lechtig, R. Martorell, V. Mejía Pivaral, P. Russell, and C. Yarbrough[3]

A study of children from four chronically malnourished Guatemalan villages has demonstrated a significant association between food supplementation during pregnancy and lower prevalences of growth retardation and infant mortality. Supplementation of the children's diets also correlated with better performance on psychological tests.

Introduction

Infant mortality is a major public health problem in developing countries, where an average of almost two out of every 10 liveborn infants die within their first year. By comparison, in the developed countries only about two out of every 100 infants die in the first 12 months.

At the same time, physical growth retardation at birth and during the first year of postnatal life is widespread in many poor communities around the world. And it is known that babies with early growth retardation are less likely to survive than those whose growth has been normal. Furthermore, babies with physical growth retardation frequently perform poorly in tests of mental development. It is widely believed that the factors accounting for most of the growth failure, developmental retardation, and high mortality in developing countries are environmental in nature and therefore can be prevented.

Maternal and child malnutrition has been postulated as one of several factors contributing to these high rates of developmental retardation and infant death. However, confirmation of its role has been difficult in populations with chronic moderate malnutrition—partly because of the imprecision involved in defining maternal and child nutritional status and partly because information is lacking on other important factors (such as socioeconomic status and infections) that might provide alternative explanations. Therefore, until now it has not been possible to infer a causal association between nutrition and developmental retardation or infant mortality, nor has it been possible to estimate the expected decline in the prevalence of these conditions

[1]Paper originally presented at the XIV Meeting of the PAHO Advisory Committee on Medical Research (Washington, 7-11 July 1975); also appearing in Spanish in *Bol Of Sanit Panam*, 1977.

[2]Research supported by grant PH 43-65-640 from the National Institute of Child Health and Human Development, U.S. National Institutes of Health, Bethesda, Maryland, U.S.A.

[3]All of the Division of Human Development, Institute of Nutrition of Central America and Panama, Guatemala City, Guatemala. Dr. Klein is Head of the Division.

that could be produced by improved nutrition.

The analysis that follows is based on a study in which food supplements were given to pregnant and lactating women and their children in four rural Guatemalan villages. Subsequent changes in the children's physical size, mental development, and health were then measured, and various factors capable of obscuring or influencing the postulated effects of improved nutrition were investigated.

Materials and Methods

Experimental Design

The present analysis was based on data provided by an earlier longitudinal investigation of the effects of chronic malnutrition on physical growth and mental development (*1*). Table 1 lists the variables that were monitored, as well as the general types of information that were gathered. Two food supplements, *atole*[4] and *fresco*,[5] were used, each being given in two villages. Attendance at the supplementation center was voluntary, and consequently there was a wide range in intake. The preparations were chosen for their nutrient content (Table 2): *fresco* had no protein and provided only one-third of the calories present in an equal volume of *atole*, but both had similar concentrations of vitamins and minerals whose absence could possibly be limiting factors in the local diet.

Table 1. Design of the experiment.

Supplement provided in four villages:

- Study population of two villages received *atole*,[a] a protein-calorie supplement
- Study population of two villages received *fresco*,[b] a calorie supplement

Information collected from mothers and children:

- Independent variables:
  - Subjects' attendance at feeding center
  - Amount of supplement ingested
- Dependent variables:
  - Assessment of child's physical growth
  - Assessment of child's mental development
- Other data:
  - Mother's obstetric history[c]
  - Details of the delivery
  - Details of clinical examination
  - Family dietary status
  - Maternal morbidity status
  - Family socioeconomic status

[a]A gruel commonly made with corn.
[b]A cool, refreshing drink.
[c]Based on diagnosis of pregnancy by absence of menstruation.

The Study Population

Moderate malnutrition and infectious diseases are endemic in the four villages, and the median family income is only about US$200 a year. The typical house is built of adobe and has no sanitary facilities. Drinking water is contaminated with enteric bacteria. Corn and beans are the principal staples of the home diet, animal protein providing some 12 per cent of total

Table 2. Nutrient content of the food supplements (180 ml).[a]

	Atole	*Fresco*
Total calories (Kcal)	163.0	59.0
Protein (g)	11.0	—
Fats (g)	0.7	—
Carbohydrates (g)	27.0	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
Fluoride (mg)	0.2	0.2

[a]Review date 11 October 1973; figures rounded to the nearest tenth of a unit.

[4]Local name for a gruel commonly made with corn.
[5]Local name for a cool, refreshing drink.

protein intake. The average mother's height and weight are low — 149 cm and 49 kg, respectively. Among the women studied the number of previous deliveries varied from zero to 13 and the reproductive age ranged from 14 to 46 years.

Variables and Sample Size

Ingestion of supplemented calories was selected as the criterion for assessing supplement intake, since the home diet appeared to be more limiting in calories than in proteins (*2*). It should be stressed, however, that while calories appeared to be limiting in this study population, other populations may experience very different nutritional conditions. The main variables measured were: prevalence of physical growth retardation at birth and at 36 months of age, psychological test performance at birth and at 24 and 36 months of age, and infant mortality.

Table 3 gives the size of the sample studied for each of the variables. The total sample of 1,083 children included 671 born during the period January 1969-February 1973, as well as 412 already living who were under 3 years of age when data collection began in January 1969.

Table 3. Size of the population samples studied.

	Children born into the study	Total children in the study
Total children available	671	1,083
Children tested for physical growth		
At birth	405	405
At 36 months	330[a]	581[a]
Children tested for mental development		
At birth	157	157
At 6 months	472	472
At 15 months	452	460
At 24 months	453[a]	480[a]
At 36 months	329[a]	565[a]
Children dying in 1st year of life	44	—

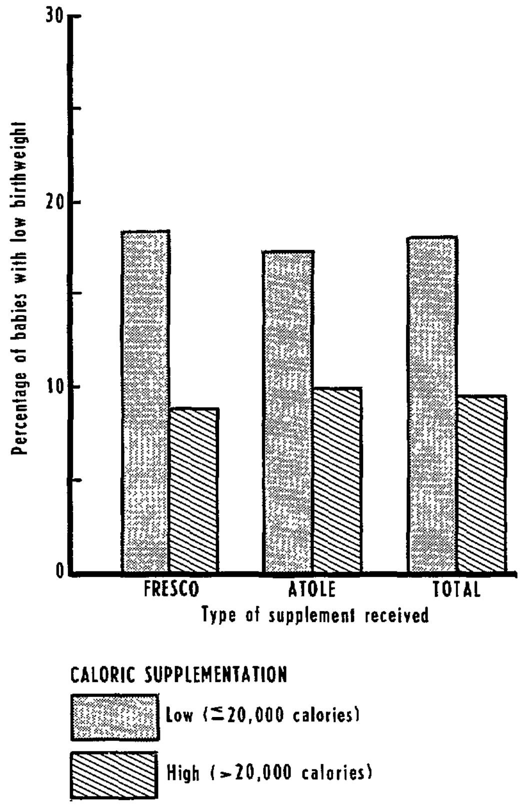
[a]Up to 30 November 1974.

Results and Discussion

Physical Growth Retardation

Supplement ingestion and birthweight. Figure 1 shows the percentages of low birthweight babies (2,500 g or less) according to the kind and amount of supplementation

Figure 1. Correlation between caloric supplementation (*fresco* or *atole*) during pregnancy and delivery of low-birthweight babies (≤ 2,500 g).



received by the mother. The mothers are divided into four groups, depending on whether they received *atole* or *fresco* and whether they received over 20,000 calories of supplementation during their pregnancies or less than that amount. There were 68 women in the high-calorie (over 20,000) *fresco* group, 118 in the low-calorie *fresco* group, 102 in the high-calorie *atole* group, and 117 in the low-calorie *atole* group. The proportion of mothers producing low-birthweight infants was lower in the two high-calorie groups. In fact, the risk of delivering a low-birthweight baby was only about half as great as it was for women in the low-calorie groups. Since home caloric intake was similar in all the groups, it is safe to assume that the calories received from the supplements were in fact additional calories in the maternal diet. Among the high-calorie subjects, the extra amount ingested appears to have averaged about 35,000 per pregnancy, or roughly 125 a day.

This association between birthweight and supplement intake cannot be accounted for by the other major maternal variables considered—home diet, body height and/or weight, morbidity, obstetric characteristics, or socioeconomic status. Nor can it be explained by individual maternal factors such as the tendency for certain mothers to have large babies, since a difference based on supplementation was observed in consecutive siblings. It could thus be concluded that if the same mother consumed more calories during one pregnancy than another, there was a tendency for the baby of that pregnancy to be heavier at birth. The result of the analysis, therefore, is that in the population studied caloric supplementation during pregnancy *caused* the decrease in the proportion of low-weight babies.

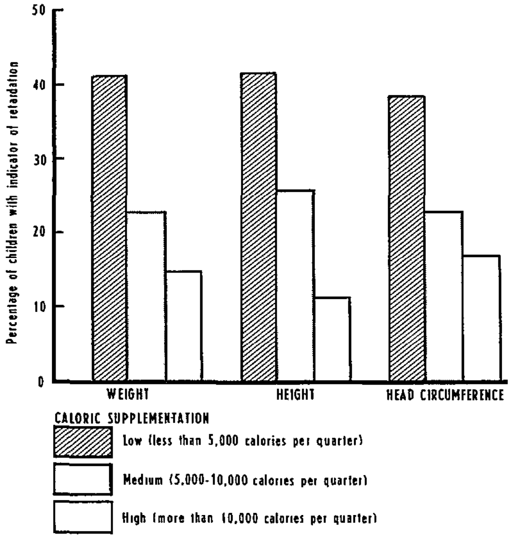
The matter of protein intake requires comment. In the particular population under study the protein-calorie ratio in the home diet was high, on the order of 1:9. Hence it was considered feasible to improve the mothers' total diet by merely adding more calories. In other populations with other diets, however, the situation might be entirely different. The best supplement for one population might not necessarily be the best for another; indeed, it might even be harmful rather than beneficial (*3*).

Growth at 36 months of age. For purposes of the present analysis retardation of growth (whether of weight, height, or head circumference) was defined as any deficit placing the subject in the lower 30th percentile of the study population. Since this limit is 10 centiles lower than the Denver standard (*4*), and since it was not felt that the populations differ in genetic potential (*5*), such a deficit, the authors consider, can well be regarded as true retardation. For example, in the case of weight the lower limit corresponded to a point equivalent to 78 per cent of the mean weight of the Denver standard (*4*).

The children with retardation in weight, height, or head circumference at 36 months of age were grouped according to whether they received a low, medium, or high amount of caloric supplement (Figure 2). If a child received more than 10,000 supplemental calories per quarter for at least 14 quarters, either directly or through its mother, it was assigned to the "high" category; if the number of calories was between 5,000 and 10,000, it was placed in the "medium" group; and if the amount was less than 5,000, the level of supplementation was considered "low." The data point to a strong correlation between the level of supplementation and all three kinds of physical growth retardation.

The comparisons above, however, fail to reflect two significant factors: the type of supplement (*atole* or *fresco*) is not specified; and children who were born too early to receive supplementation (in 1966, 1967, or 1968) are mixed in with those who could have received the supplement but did not. Data permitting analysis by type of supplement and taking into account only those children born after the study started are

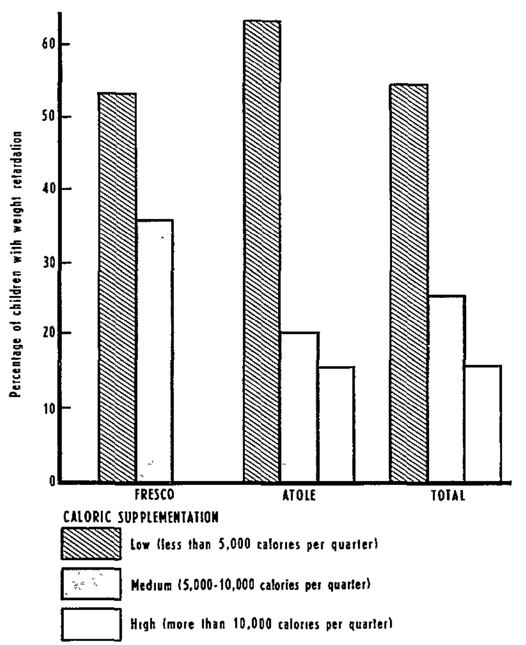
Figure 2. Correlation between caloric supplementation (both maternal during pregnancy and of the child up to 36 months) and indicators of growth retardation
(total 581 children, *fresco* and *atole* combined).



presented for weight retardation in Figure 3. The differences among children who could not have received the supplement and the differences among children who could have but did not were the same or very nearly so. The data also show, however, that the children who received a medium amount of calories via *fresco* were more likely to be small than those who received a comparable amount via *atole*. This observation again raises the question of the separate roles of protein and calories in the diet of the study population. Further investigation of this subject is currently underway.

Still, it should be stressed that an association between caloric supplementation and reduced prevalence of growth retardation was evident in all the four villages. That is to say, the proportion of growth-retarded children was consistently greater in each low-supplement group than in the middle- or high-supplement group in the same village. Furthermore, in the overall four-village sample the risk of growth retardation was nearly three times greater among the children who received a low amount of supplement than it was in the high-supplement group. Both in the analysis of birthweight and in that of growth retardation the associations observed were replicated in analyses of variance and in regressions. Moreover, the associations could not be explained by maternal variables such as home diet, body height and/or weight, morbidity, obstetric characteristics, or socioeconomic status. Thus the present authors now consider this relationship to be *causal*, estimating that the final result of continued food supplementation up to seven years of age would close the gap between the Denver height standard and the average height of the low-supplement children by about 50 per cent (*6*).

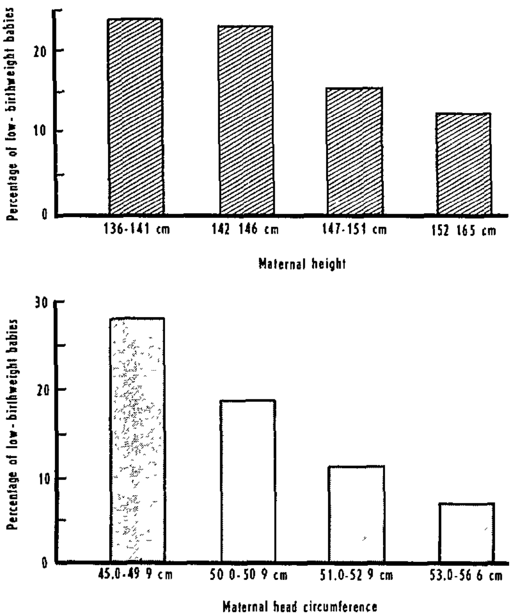
Figure 3. Correlation between caloric supplementation (both maternal during pregnancy and of the child up to 36 months) and weight retardation, by type of supplement received.



Birthweight and maternal measurements.

Maternal head circumference and height were shown to be associated with birthweight: smaller mothers tended to have smaller babies (Figure 4). Since the bulk of adult head circumference and height retardation results from events occurring in the first few years of life, the association between maternal measurements and birthweight could possibly mirror the effect of *early* maternal nutrition on subsequent fetal nutrition. Other maternal anthropometric variables are currently under investigation. It has been found, for example, that a significant association exists between birthweight and maternal arm circumference. It is felt that this latter correlation may reflect the influence of the mother's more recent nutritional status.

Figure 4. Correlation between low birthweight and the mother's height and head circumference.



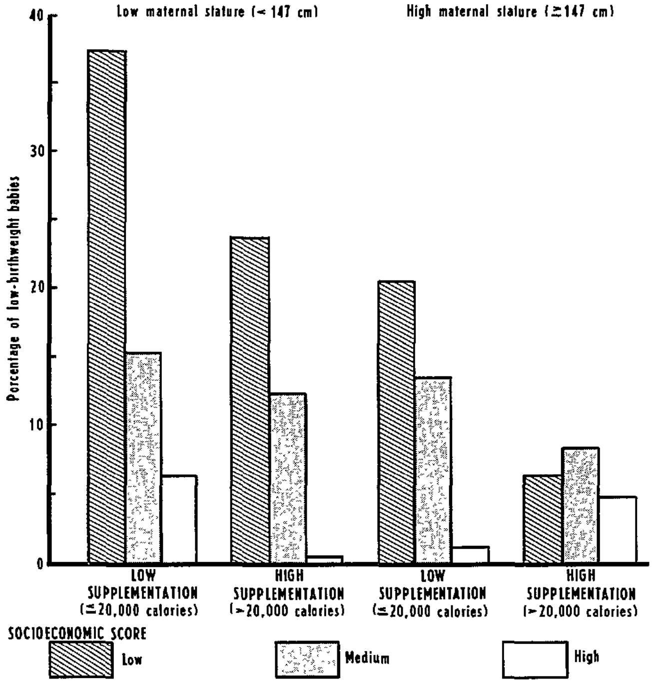
Birthweight and maternal morbidity during pregnancy. A pooled indicator of morbidity during pregnancy, composed of the sum of days ill with diarrhea or anorexia and of days confined for other sickness, correlated negatively with birthweight (Table 4). The proportion of low-birthweight babies was 33.3 per cent among the high-morbidity mothers, compared with 10.5 per cent among the low-morbidity group. Since the mothers with high morbidity also tended to have a low home caloric intake, the preliminary interpretation of these results is that morbidity during pregnancy is apt to be associated with low dietary intake, which in turn results in retardation of fetal growth (*7*).

Birthweight and cord levels of IgM. There is evidence that high cord levels of IgM may be a sign of intrauterine infection, and also that at least several intrauterine infections are associated with low birthweight (*8*). The overall study population in the four villages showed some but not

Table 4. Correlation between birthweight and measures of maternal morbidity.

Indicator of morbidity	Correlation value	Number of high-morbidity cases	Probability value less than
Pooled score of days ill with diarrhea or anorexia plus days confined for other illness	-.15	249	.05
Cord IgM level	-.10	170	.10

Figure 5. Low birthweight correlated with level of food supplementation and maternal stature, by socioeconomic status.



significant correlation between higher cord IgM levels (over 20 mg per cent) and lower birthweight (Table 4). This observation could mean that heavier babies produce greater quantities of antibodies, or else that intrauterine infection tends to produce both increased levels of IgM and retardation of fetal growth (*9*).

Birthweight and socioeconomic factors. In the study population a low family socioeconomic score and low maternal height were found to be correlated with low birthweight (Figure 5). This association has important implications for public health (*10*).

Significance of low birthweight. It has been established that low-birthweight babies have greater rates of infant mortality than babies with higher birthweight (*11*). This means that nutritional programs aimed at decreasing infant mortality could maximize their effectiveness if they were focused on mothers at high risk of delivering low-birthweight babies. Accordingly, identification of some of the maternal characteristics associated with such births may be useful in developing methods for anticipating the likelihood of low-weight births and for selecting target populations for nutritional intervention—methods that could be applied effectively among populations that do not have adequate health services (*12*).

Determinants of Psychological Test Performance

Psychological testing was done at intervals over the period from the children's birth through 36 months of age. It was

Table 5. Test-retest and interobserver reliability of psychological test measures.

Type of test	Test-retest	N	Inter-observer	N
Brazelton Neonatal Evaluation Scale				
BB1	.61	20	.93	20
BG1	.67	20	.97	20
Composite Infant Scale				
6 months, mental	.88	20	.82	15
6 months, motor	.92	20	.82	15
15 months, mental	.88	20	.87	15
15 months, motor	.87	20	.87	15
24 months, mental	.86	20	N.A.[a]	–
24 months, motor	.44	20	N.A.[a]	–
Preschool battery (36 months)				
Cognitive composite	.87	40	–[b]	–
Embedded figures test, sum	.81	20	.99	140
Embedded figures test, time	.63	20	.99	140
Embedded figures test, adaptability	.63	20	–[b]	–
Digit memory	.65	20	.99	140
Memory for sentences	.60	20	.99	140
Reverse discrimination learning, sum	.60	40	–[b]	–
Reverse discrimination learning, time	.17	20	N.A.[a]	–
Picture-namings	.86	20	1.00	140
Recognition	.91	20	.99	140
Verbal inferences	.62	20	N.A.[a]	–
Slow line-drawing	.65	20	.99	140
Puzzle-solving	.45	20	.97	140

[a]Not available.
[b]Not appropriate; score is constructed, not observed.

considered that the data collected were sufficient in quantity and the sample large enough to allow the authors to address the question of a relationship to food supplementation.

Two standards were used as a measure of food supplementation: first, the total amount ingested by the mother during her pregnancy and lactation together with that received by the child directly up to the time of evaluation; and second, the child's intake used in arriving at the high, medium, and low levels reported in Figure 2. The principal difference between these two measures is that the first reflects total ingestion over the entire span of time while the second, a weighted figure, indicates the specific amounts of supplement received during discrete segments of the child's life.

The various psychological performance tests were selected on the basis of theoretical and statistical criteria from a larger battery which has been discussed in detail elsewhere (*13*). The test-retest and interobserver reliability of the test measures are indicated in Table 5. From these figures it can be seen that there is ground for speaking with some precision about the relationships encountered between psychological test performance and food supplementation.

Table 6 shows the association observed between mental development test scores and supplement ingestion at various ages.

With regard to the newborn, perform-

Table 6. Correlation between food supplement intake and psychological test performance.

Type of test	Standard deviation (approximate)		Test scores, grouped according to levels of supplement intake[a]			F	Correlation with total supplement intake	No. tested[b]
			Low	Medium	High			
Brazelton Neonatal Evaluation Scale								
BB1	Average	12.2	39.69	40.00	39.54	.02	-.032	157
	No. tested		42	32	83			
BG1	Average	13.5	38.83	36.00	39.05	.66	-.042	157
	No. tested		42	32	83			
Composite Infant Scale								
6 months, mental	Average	13.8	73.8	76.3	77.8	2.87[c]	.030	472
	No. tested		150	221	101			
6 months, motor	Average	14.8	70.0	70.6	72.7	1.13	-.017	472
	No. tested		150	221	101			
15 months, mental	Average	12.5	62.9	67.8	72.3	4.65[d]	.130[d]	460
	No. tested		140	243	77			
15 months, motor	Average	15.0	73.8	77.2	82.6	6.25[d]	.134[d]	460
	No. tested		140	248	77			
24 months, mental	Average	12.3	61.6	65.5	68.1	8.45[d]	.161	480
	No. tested		206	192	82			
24 months, motor	Average	18.5	67.5	74.4	78.9	11.61[d]	.221[d]	480
	No. tested		206	192	82			
36-month battery cognitive composite	Average	280.3	-5.28	48.97	54.20	2.75	.060	565
	No. tested		278	237	50			
Embedded figures, sum	Average	3.4	9.43	10.03	9.70	1.91	.069[c]	552
	No. tested		270	232	50			
Embedded figures, time	Average	11.4	31.5	30.1	28.9	1.58	-.079[c]	552
	No. tested		270	232	50			
Embedded figures, adaptability	Average	24.0	9.42	12.71	72.40	1.48	.023	552
	No. tested		270	232	50			
Digit memory	Average	8.3	10.11	10.87	12.92	2.22	.073	465
	No. tested		224	197	44			
Memory for sentences	Average	12.8	12.6	14.22	14.60	1.85	.076	486
	No. tested		228	210	48			
Reverse discrimination learning, sum	Average	20.5	23.18	23.83	20.93	.38	-.061	497
	No. tested		232	220	45			
Reverse discrimination learning, time	Average	11.0	23.4	20.7	18.3	5.13[d]	-.176[d]	497
	No. tested		232	220	45			
Picture-naming	Average	4.3	6.44	7.44	8.06	5.07[d]	.117[d]	539
	No. tested		262	227	50			
Recognition	Average	5.6	19.40	20.62	20.70	2.83[c]	.060	539
	No. tested		262	227	50			
Verbal inferences	Average	1.2	1.25	1.52	2.08	3.28[c]	.157[d]	238
	No. tested		120	106	12			
Slow line-drawing	Average	45.0	105.9	93.4	94.4	4.84[d]	.121[d]	520
	No. tested		250	220	50			
Puzzle-solving	Average	5.4	5.98	5.86	6.46	.25	.0002	476
	No. tested		203	223	50			

[a]Low = under 5,000 calories per quarter for 14 quarters; medium = between 5,000 and 10,000; high = over 10,000.

[b]Up to 30 November 1974.

[c]$p < .05$.

[d]$p < .01$.

ance 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 analysis of all the test items. BB1 includes negative signs of tonus, motor maturity, vigor, pull to sit, visual following and interest in the examiner, and trembling. BGI is in some respects the opposite of BB1, since it includes positive signs of some of the same things, including vigor, visual following, social interest in the examiner, and motor maturity.

The next set of tests corresponds to the Composite Infant Scale taken at six, 15, and 24 months of age. This scale, a mixture of psychomotor items, provides both a mental and a motor score for each of the testing periods. At six months of age only the mental score was significantly associated with supplement ingestion. From age 15 months onward, however, there was a clear pattern: well-nourished subjects performed significantly better in the motor as well as the mental category. This was so both for the discrete measure of high, medium, and low levels of supplementation and for the measure of total supplement ingestion.

The individual test items used in the Composite Infant Scale at 15 and 24 months of age were examined separately. In general, the impact of supplement ingestion seems to have been more closely related to motor and manipulative skills than to language and other emerging cognitive abilities. However, the tests themselves are heavily weighted with motor and manipulative items, since these are the principal behavioral characteristics which infants uniformly display at 15 and 24 months of age.

Cognitive abilities begin to emerge rapidly starting at three years, and for this reason performance at later ages is of interest. Psychological performance and its relationship to food supplement ingestion was examined in children 36 months of age using a psychometric battery designed to test numerous and diverse skills. Of 13 variables examined, five revealed significantly better performances by well-supplemented children than by poorly supplemented ones and five others showed trends in this direction (Table 6). The most significant associations were in picture-naming and recognition (both estimates of child vocabulary) and in verbal inferences (a verbal reasoning test). The two other tests that showed a significant correlation were the response time for the reverse discrimination learning task and the line-drawing task, in which the child is asked to draw a line as slowly as possible. In both instances the food-supplemented children had better average levels of performance.

At this age there were relatively few sex differences with respect to the impact of food supplementation. In general, performances by boys and girls were quite comparable across the board, the two sexes responding similarly to food supplementation with very few exceptions.

The timing of supplementation also appeared to affect psychological test performance. Table 7 shows correlations and partial correlations of supplement ingestion with Composite Infant Scale mental scores at six, 15, and 24 months, and also with cognitive composite and verbal inference scores at 36 months. Column 1 gives the correlation with previous supplementation of the mother's diet during pregnancy; column 2 shows the correlation with cumulative supplement ingested by the child and its mother up to the time of testing; column 3 indicates the correlation of test performance with cumulative supplementation when maternal supplementation during pregnancy is partialed out; and column 4 shows the reverse of column 3: correlation with supplement ingested during pregnancy after postnatal intake is partialed out.

Not only are the correlations between gestational supplementation and later test performance significant, but also, what is

Table 7. Correlation between pattern of food supplementation and psychological test performance.

Age of children[a] and type of test	Correlation with pattern of food supplementation			
	Intake during pregnancy	Total intake to time of testing	Controlling for supplement ingested during pregnancy	Controlling for postnatal supplement to time of testing
Boys:				
6 months, CIS[b] mental	.11	.04	-.07	.13[c]
15 months, CIS mental	.09	.14[c]	.11	.01
24 months, CIS mental	.20[d]	.19[d]	.11	.12[c]
36 months, cognitive composite	.09	.04	.00	.12[c]
36 months, verbal inferences[e]	.36[d]	.20[d]	.04	.33[d]
Girls:				
6 months, CIS mental	.13[c]	.01	-.18[d]	.15[c]
15 months, CIS mental	.24[d]	.12[c]	-.07	.22[d]
24 months, CIS mental	.15[c]	.13[c]	.04	.09
36 months, cognitive composite	.11	.10	.04	.05
36 months, verbal inferences[e]	.25[d]	.12[c]	-.03	.23[d]

[a]Total of 250 subjects for all but verbal inferences test.
[b]Composite Infant Scale.
[c]$p < .05$.
[d]$p < .01$.
[e]120 subjects only in the combined sample of boys and girls.

even more interesting, once gestational supplementation is removed from consideration there is no longer any relevant pattern of association. Moreover, the correlation with prenatal supplementation is not diminished when later supplementation is partialed out. Thus, pregnancy is the crucial period for supplementation as far as later psychological test performance is concerned.

It was recognized that the design of the study in question, like that of many large-scale intervention studies, does not completely eliminate the opportunities for possible confusion and subsequent misinterpretation of results. Accordingly, a series of detailed analyses were conducted exploring other possible interpretations of the results just presented. First, associations between food supplementation and psychological test performance were examined among children with the same mother. Thus, these analyses were controlled for family socioeconomic status, as well as other family-level variables. As in the case of birthweight, statistically significant relationships emerged. That is to say, even among siblings the mother's greater intake of supplement during one specific pregnancy was found to be associated with superior test performance later on by that particular child.

A variety of other potential contributing factors were also analyzed. These included the possible effect of: repeated psychological testing, child morbidity, level of parental cooperation with the project, differences among the four villages. In addition, consideration was given to the possible impact of attendance at supplementation centers per se on mental development, as well as the general problem of social and economic differences among the families of the children involved. For the most part, however, these factors do not provide a reasonable alternative explanation for the relationship observed between food supplement ingestion and improved psychological test performance. Curiously, at 36 months of age there seemed to be an inverse relationship between family socioeconomic status and food supplement intake. That is, there was a tendency for children who received more supplement to have lower family socioeconomic status scores than those who received less supplement. This tendency was not statistically significant for the total sample, although in some individual villages it was significant. In view of this negative correlation, the superior performance of the well-supplemented children is even more striking, since it would be expected that if supplementation had produced no effect the children with the higher socioeconomic status would have scored higher on the psychological tests. Thus, comparison of the psychological test scores of the groups receiving high, medium, and low levels of supplement without regard for socioeconomic status is a conservative test of the association between supplementation and psychological performance.

A similar pattern was observed with respect to the children's home diet. Those in the least supplemented group tended to have more adequate home diets than those who received large amounts of supplement. For calories in the home diet this relationship was not significant; however, at all ages the least supplemented children had more adequate protein in their home diets than did the ones receiving high supplementation.

These findings suggested that the effects of supplementation would vary according to socioeconomic status, particularly at the later age of 36 months. Subsequent analysis based on socioeconomic levels (high or low) bore out this assumption. At 36 months food supplementation was found to have a greater effect on test performances by more socioeconomically deprived children than on performances by those who were less deprived. For boys, the results of four tests—embedded figures, sum of correct responses; embedded figures, adaptability to test; recognition vocabulary; and reverse discrimination, learning time—displayed the pattern described above. For girls the results of two tests—embedded figures, adaptability to test, reverse discrimination, and learning time—showed patterns of this type.

There is good cause for public health concern about children scoring in the lowest percentiles on mental development tests; such children are probably less likely to be independent self-sufficient members of the community than those who score in the higher ranges. Consequently, a child's relative risk of being in the lowest decile in the overall measure of mental development was calculated vis-à-vis his level of supplementation (Table 8). This comparison was based on the 36-month composite test score, which was considered the most representative measure of overall cognitive performance at that age.

If nutritional supplementation had no effect on the risk of low test performance, it would be expected that about the same proportion of children in each of the three nutritional groups would fall into the lowest decile. However, analysis revealed that the proportion of low-supplement children in the lowest decile (13 per cent) was more than twice as great as that of the high-supplement group (6 per cent). Similarly, 16 per cent of the high-supplement children scored in the highest decile, whereas only 7 per cent of the low-supplement group did. Moreover, when high versus low scores were compared within the low-supplement group, the low-supplement child was nearly twice as likely to fall in the

Table 8. Psychological test performance (36 months, cognitive composite) correlated with both food supplementation and socioeconomic status, showing relative risk of falling into the extreme lowest or top deciles.

Supplement intake category	Absolute distribution of the children tested				Percentage distribution of the children tested				Chi-square test		
	Lowest decile	Intervening deciles	Highest decile	Total	Lowest decile	Intervening deciles	Highest decile	Total	X^2	df	p
Whole sample											
Low supplement	35	224	19	278	13	80	7	100	9.4	4	< .05
Medium supplement	19	185	29	237	8	80	12	100			
High supplement	3	39	8	50	6	78	16	100			
Total	57	452	56	565	10	80	10	100			
Low socioeconomic status[a]											
Low supplement	16	104	3	123	13	85	2	100	9.3	4	< .10
Medium supplement	13	94	13	120	11	78	11	100			
High supplement	2	19	4	25	8	76	16	100			
Total	31	217	20	268	12	81	7	100			
High socioeconomic status[a]											
Low supplement	18	116	16	150	12	77	11	100	5.0	4	NS
Medium supplement	6	95	15	116	5	82	13	100			
High supplement	1	20	4	25	4	80	16	100			
Total	25	231	35	291	9	79	12	100			

[a]No socioeconomic score data were available for the families of six children.

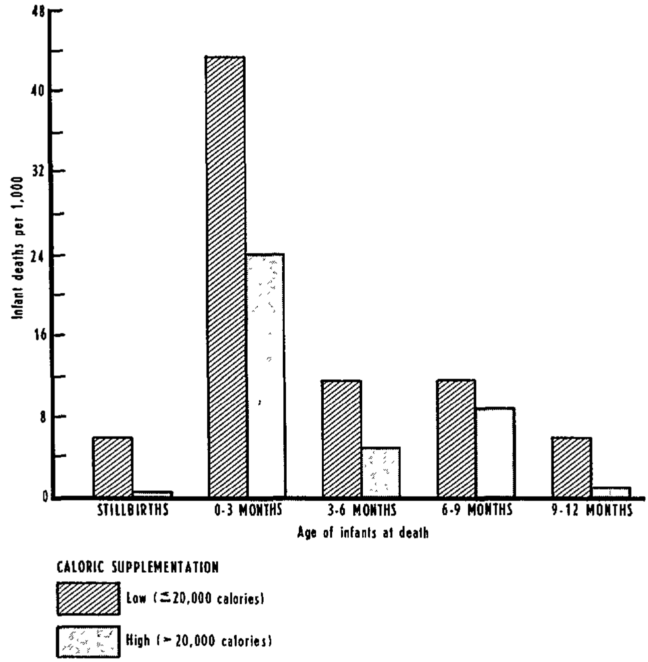
lowest decile as opposed to the highest. At the same time, a child in the high-supplement group was more than twice as apt to land in the highest decile. Nutritional supplementation was also found to have a significant effect for children in the eight intervening deciles.

When these analyses were done with respect to socioeconomic status, a child with a high score but low supplementation was found to have about the same probability of being in the highest decile as in the lowest. However, a child with a low score and low supplementation had more than a sixfold greater risk of being in the lowest decile than in the highest. When all the children were considered, it was found that nutritional status had a greater impact on the test performance of the high socioeconomic scorers than on that of the low socioeconomic scorers.

In summary, the analyses to date suggest that food supplementation does affect psychological test performance. The impact can be seen reasonably clearly at 15 months of age and continues to be apparent at 24 and 36 months of age. Moreover, food supplementation during pregnancy appears to have a greater effect on psychological test performance than does later food supplementation. These findings are consistent with observations reported earlier for this project (*14*).

Finally, a variety of other possible factors failed to provide reasonable alternative explanations for the results reported here. However, one of these factors, socioeconomic status, does appear to interact with food supplementation: at 36 months children from families with low socioeconomic scores in the study population were more affected by supplementation than were children from families with relatively high socioeconomic scores.

Figure 6. Correlation between caloric supplementation during pregnancy and lactation and infant mortality.



Determinants of Infant Mortality

Figure 6 shows a comparison of caloric supplementation during pregnancy and lactation, with stillbirth or infant death during the first year of life. Mortality was consistently higher in the low-supplement group than in the high-supplement group. Indeed, the risk of dying during the first year of life in the high-supplement group was only half what it was in the low-supplement group.

The observation that improved nutrition during pregnancy and lactation reduced infant mortality by nearly half deserves special comment. Until now, intervention programs aimed at combating infant mortality have tended to focus on the control of infectious diseases through the provision of adequate health services and have paid relatively little attention to nutrition. The present results demonstrate that nutritional intervention may have an exceedingly important role in reducing infant mortality among poor rural populations.

Other variables were also associated with infant mortality: low socioeconomic status, low maternal height, low gestational age, severe hypoxia at birth, and low birthweight (*15*). These five variables, either alone or in combination, can serve as useful indicators for identifying children who need special attention in public health programs.

Conclusions

For the rural populations studied, food supplementation received by the mother during pregnancy and the infant thereafter was associated with important reductions in both infant mortality and the prevalence of physical growth retardation among children up to 36 months of age. Nutrition also appeared to be associated with psychological test performance. Taken together, maternal height, head circumference, and arm circumference, together with family socioeconomic status, can be indicative of the risk of delivering a low birthweight baby. The efficiency of nutritional programs seeking to reduce growth retardation and infant mortality could be significantly enhanced if efforts were concentrated on women who are vulnerable in terms of these variables.

Final Remarks

It should be pointed out that food supplementation as used in the study was an investigative device; the technique employed would not be appropriate for programs serving large populations over long periods of time. In many preindustrial societies the elimination of poverty itself would be the most effective way of improving nutritional status and reducing the prevalence of developmental retardation and infant mortality.

SUMMARY

The results of a food supplementation study conducted in four chronically malnourished rural villages in Guatemala were analyzed to determine possible effects on the study children's early mental and physical development. One of two food supplements, *atole* and *fresco*, were given to pregnant and lactating mothers and the infants born to them up to three years of age. The level of supplement received was noted and the subsequent course of the children's development observed.

Food supplementation of pregnant mothers was found to correlate with higher weights of their babies at birth. No other major maternal variables—home diet, body height and/or weight, morbidity, obstetric characteristics, or socioeconomic status—could account for this association.

At 36 months of age the children who had received a large amount of food supplementation showed a far lower prevalence of growth retardation than did those who received smaller quantities. Again, this correlation could not be attributed to any other major maternal variables.

In regard to mental development, food supplementation was found to correlate with better performance in psychological tests beginning at six months of age. At 36 months the correlations were significant in five different tests.

The results of this analysis have wide-ranging implications for public health. Given the recognized association between low birthweight and infant mortality, they point especially to the importance of maternal nutrition during pregnancy in programs aimed at reducing this serious problem.

REFERENCES

(*1*) Klein, R. E., J-P. Habicht, and C. Yarbrough. Some methodological problems in field studies of nutrition and intelligence. In: D. J. Kallen (ed.), *Nutrition, Development, and Social Behavior*. DHEW Publication No. (NIH) 73-242. Washington, U.S. Department of Health, Education, and Welfare, Public Health Service, National Institutes of Health, 1973. pp. 61-75.

(*2*) Lechtig, A., J-P. Habicht, H. Delgado, et al. Effect of food supplementation during pregnancy on birthweight. *Pediatrics* 56:508-520, 1975.

(*3*) Martorell, R., A. Lechtig, C. Yarbrough, et al. Protein calorie supplementation and postnatal physical growth: A review of findings from developing countries. *Arch Latinoamer Nutr* 26:115-128, 1976.

(*4*) Hansman, C. Anthropometry and related data. In: R. W. McCammon (ed.), *Human Growth and Development*. Charles C. Thomas, Springfield, 1970. pp. 101-154.

(*5*) Habicht, J-P., R. Martorell, C. Yarbrough, et al. Height and weight standards for preschool children: Are there really ethnic differences in growth potential? *Lancet* 1:611-615, 1974.

(*6*) Institute of Nutrition of Central America and Panama, Division of Human Development. Nutrición, crecimiento y desarrollo. *Bol Of Sanit Panam* 78:38-51, 1975.

(*7*) Lechtig, A., J-P. Habicht, G. Guzmán, et al. Morbilidad materna y crecimiento fetal en poblaciones rurales de Guatemala. *Arch Latinoamer Nutr* 22:243-253, 1972.

(*8*) Alford, C. A., J. W. Fort, W. J. Blankenship, et al. Subclinical central nervous system disease of neonates: A prospective study of infants born with increased levels of IgM. *J Pediatr* 75:1287-1291, 1969.

(*9*) Lechtig, A., L. J. Mata, J-P Habicht, et al. Levels of immunoglobulin M (IgM) in cord blood of Latin American newborns of low socio-economic status. *Ecol Food Nutr* 3:171-173, 1974.

(*10*) Lechtig, A., H. Delgado, R. E. Lasky, et al. Maternal nutrition and fetal growth in developing societies: Socioeconomic factors. *Am J Dis Child* 129:434-437, 1975.

(*11*) Chase, H. C. Infant mortality and weight at birth: 1960 United States birth cohort. *Am J Public Health* 59:1618-1628, 1969.

(*12*) Lechtig, A., H. Delgado, C. Yarbrough, et al. A simple assessment of the risk of low birth-weight to select women for nutritional intervention. *Am J Obstet Gynec* 125:25-34, 1976.

(*13*) Klein, R. E., J-P Habicht, C. Yarbrough, et al. Empirical findings with methodological implications in the study of malnutrition and mental development. In: *Nutrition, the Nervous System, and Behavior*. PAHO Scientific Publication 251. Washington, Pan American Health Organization, 1972. pp. 43-47.

(*14*) Klein, R. E., C. Yarbrough, R. E. Lasky, et al. Correlations of mild to moderate protein-calorie malnutrition among rural Guatemalan infants and preschool children. In: *Symposia of the Swedish Nutrition Foundation XII*. Uppsala, Almquist and Wiksell Informations-industri AB, 1974. pp. 168-180.

(*15*) Lechtig, A., H. Delgado, R. Lasky, et al. Effect of improved nutrition during pregnancy and lactation on developmental retardation and infant mortality. In: P. L. White and N. Selvey, (eds.), *Proceedings of the Western Hemisphere Nutrition Congress IV, 1974*. Acton, Mass., Publishing Sciences Group Inc., 1975. pp. 117-125.