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# DIETARY QUALITY AND DEVELOPMENTAL OUTCOMES OF CHILDREN IN EGYPT, KENYA AND MEXICO

Interim Report

Nutrition Collaborative Research Support Program

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Nutrition Collaborative Research Support Program

in

Egypt, Kenya and Mexico

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Nutrition: Functional Implications of Malnutrition

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## SUMMARY

A significant number of children in all three country projects of the Nutrition Collaborative Research Support Program (NCRSP) showed faltering growth as early as the third month of life. The very early age at which growth faltering begins in these populations was an unexpected and important finding. Growth stunting is established in the first year of life. Body size of infants and toddlers correlates with indices of both motor and mental development, the bigger the child the better the score. Thus, smaller children may well be at risk for later cognitive deficits and poor learning performance.

The NCRSP identified dietary quality as an important factor in early growth faltering. The quality of the diet of pregnant and lactating women and of infants and children correlates strongly with improved behavioral and cognitive performance by their infants and children.

NCRSP researchers have consistently found greater associations between functional outcomes and dietary quality (as measured by animal source protein and energy) than between those outcomes and dietary quantity (as measured by total energy and protein). Moreover, preliminary analyses show an association between dietary quality and cognitive and developmental measures for infants, preschoolers and school-age children. New improved measures of dietary quality show that the mean protein quality and quantity of children's diets was adequate, but both the quality and possibly bioavailability of several micronutrients (e.g. zinc and iron) were only marginally adequate in all three country-sites. More detailed investigation using newer and more sophisticated analyses is urgently needed. If confirmed, these findings have major food policy implications throughout the developing world.

This report on five papers by NCRSP investigators excerpted below describes recent research on relationships between dietary quality, cognition and developmental outcomes in infants and children.

New Nutrient Data Base to Assess Dietary Quality

NCRSP researchers reduced the NCRSP food data base of several thousand food descriptors into an international food list of 234 foods representing all foods consumed by the respondents in the three project countries. A nutrient data base of 48 essential nutrients was then developed. From a sample of approximately 20% of diets across countries, a nutrient profile of each diet was developed employing the new nutrient data base. The diet-nutrient analysis identified nutrients most likely to be deficient in the sample diets of the three countries and therefore, most likely to be linked to poor functional outcomes.

Plans are to extend these preliminary analyses to the full data sets of each country and then to estimate the overall risks of deficiency for each nutrient by age and country. A critical second step is to identify the characteristics of diets which appear to be nutritionally adequate and which support desirable functional outcomes.

**Dietary Quality and Infant Behavior**

Preliminary findings show that dietary quality during pregnancy significantly influences neonatal behavior, e.g the newborn's ability to control his or her physiological system in response to external manipulation. Furthermore, diet quality--and to a lesser extent, the quantity of maternal food intake--during pregnancy and lactation were related to certain behavioral outcomes measured between the third and sixth month of age. For example, maternal diets, particularly those low in animal source foods, were associated with reduced infant activity level and lack of eye-focus on objects and people. These infants showed a frequent state of drowsiness. The relationships held even when other factors such as household socioeconomic status were statistically controlled.

A critical next analytical step will be to identify characteristic food group profiles of maternal diets during pregnancy and lactation which support desirable infant outcomes.

**Dietary Quality and Cognitive Development in Toddlers**

A strong correlation between dietary quality, expressed in terms of animal source foods, and cognitive outcomes of toddlers (18 to 30 months of age) were observed even when other variables, e.g. socioeconomic status and environment, were statistically controlled. A follow-up study of five-year old Kenyans who had been studied as toddlers showed that the quality of the diet consumed at 18 to 30 months of age was the strongest predictor of cognitive performance at 5 years.

Although the methods and procedures of testing cognition had to be fitted to the cultural situations of each NCRSP country, dietary quality (animal source foods) was positively associated with impaired mental performance across all three country sites. Future analyses will focus on identifying specific nutrients in toddler diets influencing cognition.

**Dietary Quality and Cognitive Development of School-Age Children**

Relationships among food intake, cognitive performance and classroom behavior in Kenyan schoolers (7-9 years) indicated significant correlations with cognitive scores. Clearly, quality of the schoolers' diet correlated more strongly and significantly with cognitive outcomes than other measures. In school-age children, particularly girls, dietary quality plays a part in the child's attention span and performance in the classroom.

Mexico data showed a significant positive correlation between cognitive measurements and diet quality. However, in some cases, socioeconomic status becomes a strong indicator of cognitive performance. Thus, in Mexico, a complex interaction between economic resources and diet is indicated.

Future plans include the analysis of Egyptian schooler data and the examinations of relationships between specific nutrient intakes and schooler performance.

**Adult Anthropometric Markers in Food Intake and Outcome Measures**

Because the NCRSP has provided data on household food intake and on body size and related characteristics of parents and children, the data can be used to look for key physical markers that would serve to classify individuals and families at risk of poor functional outcomes (such as illness, poor cognitive

development and failure to thrive). The relative fatness between spouses suggests that energy (calorie) balance may reflect shared household characteristics which can be explored in relation to intake and function. Preliminary evaluation of adult cognitive test scores suggests that cognitive performance and body size and/or fatness are related.

Policy Implications

Current findings of the NCRSP have established that populations, regularly consuming diets marginal in dietary quality, function poorly both biologically and behaviorally. The results presented in this report show clearly that factors that cause children to be stunted also impede their cognitive development and limit their school performance. The strong overwhelming association between both cognitive performance and school performance and food quality, defined specifically as animal source foods, is impressive.

These findings should convince countries and donor agencies that food quality is a most important factor which influences and optimizes cognitive development and school performance of children. Policy makers should include food quality factors (and not just quantity of food commodities) in agricultural programs and policy. This may result in putting more animal source foods on the food platters of households.

Ministries of education must reconsider guidelines in planning school feeding programs. For example, educational policy should include targeting specific quality foods to facilitate improved performance of school children.

Food and nutrition components of Maternal-Child-Health programs should include commodity foods with optimal nutrient content (e.g. adequate micronutrients) for pregnant and lactating women and for infants and young children.

The quality of diets consumed by the public should be recognized as a major catalyst to the economic development and growth of a country. Human cognitive performance is critical to human capital formation; both are dependent on quality diets. Policies directed to improve dietary quality have the potential to spark economic growth and thus, should be incorporated into long-term national economic development strategies.

# I. PRELIMINARY ESTIMATION OF DIETARY QUALITY FOR WOMEN, SCHOOLERS, AND TODDLERS IN RURAL EGYPT, KENYA AND MEXICO

**University of California, Berkeley**

Reports from all three country projects have identified potential effects of dietary quality (as measured by animal protein and/or animal-source energy intakes) on functional outcomes. Theoretically, these effects could be due to a differential in the quality of the dietary protein, since animal proteins are almost always of greater biologic quality than plant proteins. Alternatively (or perhaps, additionally), the effects could be due to nutrients which appear more commonly in animal products, and thus co-vary with animal protein and animal-source energy intakes. Yet another consideration is the increased bioavailability of certain nutrients (especially minerals) in diets that are relatively low in certain components present in plants, such as dietary fiber and phytate, which may interfere with nutrient absorption. To investigate these alternative hypotheses, we undertook estimation of across-project intakes of nutrients and other food components which might affect dietary quality. Simultaneously, we estimated both the level and the quality of dietary protein based on the amino acid profiles of the diets in each country.

A multi-country nutrient data base was developed, using the UCB Minilist for the core nutrient data. Nutrient data were obtained for 48 nutrients including 10 amino acids. Foods were added and deleted as appropriate, to give an International Minilist (Murphy, 1990). Foods reported from each country were cross-referenced to the International Minilist, and nutrient totals were accumulated for each target individual in each country. The results reported here are for a 20 to 25% subsample from each country: cluster 1 in Kenya; community 2 in Mexico, and the first 20% of observations from Egypt. Since final checking remains to be done, and since only a subsample has been examined, <u>these results must be regarded as preliminary</u>.

Estimated nutrient and food component intakes across the three countries are shown for the subsample of lead females (Table 1), schoolers (Table 2), and toddlers (Table 3). Two nutrients were below 70% of the recommended levels for all three age groups in all three countries: zinc and vitamin D. Vitamin D is not likely to be a nutrient at risk in these populations due to the body's ability to synthesize this vitamin when the skin is exposed to sunlight. Low zinc intakes, however, are of considerable concern due to the requirement of this mineral for normal growth and development.

The zinc recommendations shown in Tables 1-3 have been adjusted to assume the lowest level of bioavailability (10%) due to the high levels of dietary fiber and phytate in these diets. The zinc in the Egypt diet may be somewhat more available than in Mexico and Kenya due to the relatively lower phytate:zinc molar ratio in the diets. Wheat and corn are consumed mainly as bread in Egypt, and the leavening process destroys a substantial portion of the phytate (although the breads are "flat" by U.S. standards, they are still leavened by a yeast-based starter (Faridi et al., 1983; FAO and USDA, 1982)). Animal experiments have shown that phytate:zinc ratios below 10 are associated with adequate zinc bioavailability, while ratios greater than 20 (as in Mexico and Kenya) may be

**TABLE 1 (Preliminary)**
**Intakes of a sample[1] of NCRSP lead females**

| | Rec[2] | | | Kenya | | Egypt | | Mexico | |
|---|---|---|---|---|---|---|---|---|---|
| Nutrient | NPNL | Pg | Lact | Intake | % Rec[3] | Intake | % Rec[3] | Intake | % Rec[3] |
| Calcium (mg) | 450 | 1100 | 1100 | 279 | 62 | 395 | 88 | 1563 | 347 |
| Magnesium (mg) | 280 | 300 | 355 | 508 | 181 | 436 | 156 | 511 | 183 |
| Iron (mg) | 29 | 48 | 48 | 15 | 52 | 14 | 48 | 14 | 48 |
| Zinc (mg) | 22 | 30 | 54 | 8 | 36 | 11 | 50 | 11 | 50 |
| Copper (mg) | 1.5 | --- | --- | 1.4 | 93 | 1.7 | 113 | 1.7 | 113 |
| Vitamin A (μg RE) | 500 | 600 | 850 | 512 | 102 | 506 | 101 | 428 | 86 |
| Vitamin C (mg) | 30 | 30 | 30 | 62 | 207 | 65 | 217 | 41 | 137 |
| Thiamin (mg) | 0.9 | 1.0 | 1.1 | 1.5 | 167 | 1.2 | 133 | 0.9 | 100 |
| Riboflavin (mg) | 1.3 | 1.5 | 1.7 | 1.1 | 122 | 1.2 | 92 | 1.0 | 77 |
| Niacin (mg) | 14.5 | 16.8 | 18.2 | 13.4 | 92 | 17.0 | 117 | 16.4 | 113 |
| Folate (μg) | 170 | 370 | 270 | 328 | 193 | 392 | 231 | 257 | 151 |
| Vitamin B6 (mg) | 1.6 | 2.2 | 2.1 | 1.5 | 94 | 1.5 | 94 | 1.4 | 88 |
| Vitamin B12 (μg) | 1.0 | 1.4 | 1.3 | 0.2 | 20 | 1.5 | 150 | 2.3 | 230 |
| Pantothenate (mg) | 4.0 | --- | --- | 3.5 | 88 | 4.8 | 120 | 3.5 | 88 |
| Vitamin E (mg TE) | 8.0 | 10.0 | 12.0 | 6.1 | 76 | 9.5 | 119 | 4.7 | 59 |
| Vitamin D (μg)[4] | 2.5 | 10 | 10 | 0.7 | 28 | 0.7 | 28 | 1 | 68 |
| Dietary Fiber (g) | --- | --- | --- | 52 | --- | 38 | --- | 34 | --- |
| Phytate (mg) | --- | --- | --- | 2263 | --- | 1620 | --- | 3516 | --- |
| Phytate: zinc molar ratio[5] | --- | --- | --- | 28 | --- | 15 | --- | 32 | --- |

[1] Includes pregnant and lactating women. Kenya sample = cluster 1; Egypt sample = first 20%; Mexico sample = community 2.

[2] Rec = recommendations from international agencies summarized in Wood-Dahlstrom and Calloway, 1990; and U.S. NRC, 1989 when there is no international recommendation. Copper and pantothenate recommendations are the NRC minimum safe and adequate level. Iron and zinc recommendations adjusted for low availability. NPNL = non-pregnant non-lactating; Pg = pregnant; Lact = lactating.

[3] % rec = percent of NPNL recommendation. True percent will be different when pregnant and lactating women are removed from the sample.

[4] 1 μg Vitamin D = 40 IU.

[5] (Phytate (mg)/660)/(Zinc (mg)/65.4).

**TABLE 2 (Preliminary)**
**Intakes of a sample[1] of NCRSP schoolers**

| | | Kenya | | Egypt | | Mexico | |
|---|---|---|---|---|---|---|---|
| Nutrient | Rec[2] | Intake | % Rec | Intake | % Rec | Intake | % Rec |
| Calcium (mg) | 450 | 207 | 46 | 361 | 80 | 1061 | 236 |
| Magnesium (mg) | 170 | 424 | 249 | 341 | 201 | 340 | 200 |
| Iron (mg) | 16.0 | 12.4 | 78 | 11.6 | 73 | 8.8 | 55 |
| Zinc (mg) | 16.0 | 6.6 | 41 | 8.7 | 54 | 7.6 | 48 |
| Copper (mg) | 1.0 | 1.1 | 110 | 1.4 | 140 | 1.2 | 120 |
| Vitamin A (μg RE) | 500 | 466 | 93 | 500 | 100 | 271 | 54 |
| Vitamin C (mg) | 20 | 67 | 335 | 49 | 245 | 20 | 100 |
| Thiamin (mg) | 0.9 | 1.3 | 144 | 1.0 | 111 | 0.6 | 67 |
| Riboflavin (mg) | 1.3 | 0.9 | 69 | 1.0 | 77 | 0.7 | 54 |
| Niacin (mg) | 14.5 | 11.3 | 78 | 13.4 | 92 | 10.7 | 74 |
| Folate (μg) | 102 | 261 | 256 | 328 | 322 | 168 | 165 |
| Vitamin B6 (mg) | 1.4 | 1.3 | 93 | 1.2 | 86 | 0.9 | 64 |
| Vitamin B12 (μg) | 0.90 | 0.12 | 13 | 1.8 | 200 | 1.5 | 167 |
| Pantothenate (mg) | 4.0 | 2.8 | 70 | 3.9 | 98 | 2.4 | 60 |
| Vitamin E (mg TE) | 7.0 | 5.1 | 73 | 8.1 | 116 | 3.3 | 47 |
| Vitamin D (μg)[3] | 2.5 | 0.4 | 16 | 0.5 | 20 | 1.3 | 52 |
| Dietary Fiber (g) | --- | 44 | --- | 30 | --- | 23 | --- |
| Phytate (mg)[4] | --- | 1935 | --- | 1326 | --- | 2374 | --- |
| Phytate: zinc molar ratio | --- | 29 | --- | 15 | --- | 31 | --- |

[1] Kenya sample = cluster 1; Egypt sample = first 20%; Mexico sample = community 2.

[2] Rec = recommendations summarized in Wood-Dahlstrom and Calloway, 1990; and U.S. NRC, 1989 when there is no international recommendation. Iron and zinc recommendations adjusted for low availability. Copper and pantothenate recommendations are the minimum safe and adequate level.

[3] 1 μg Vitamin D = 40 IU.

[4] (Phytate (mg)/660)/ (Zinc (mg)/65.4).

**TABLE 3 (Preliminary)**
**Intakes of a sample[1] of NCRSP toddlers**

| | | Kenya | | Egypt | | Mexico | |
|---|---|---|---|---|---|---|---|
| Nutrient | Rec[2] | Intake | % Rec | Intake | % Rec | Intake | % Re |
| Calcium (mg) | 450 | 147 | 33 | 239 | 53 | 666 | 148 |
| Magnesium (mg) | 80 | 214 | 268 | 167 | 209 | 207 | 259 |
| Iron (mg) | 9.0 | 5.6 | 62 | 5.5 | 61 | 5.6 | 62 |
| Zinc (mg) | 16.0 | 3.2 | 20 | 4.6 | 29 | 4.8 | 30 |
| Copper (mg) | 0.70 | 0.64 | 91 | 0.72 | 103 | 0.76 | 109 |
| Vitamin A (μg RE) | 400 | 284 | 71 | 351 | 88 | 269 | 67 |
| Vitamin C (mg) | 20 | 41 | 205 | 30 | 150 | 18 | 90 |
| Thiamin (mg) | 0.50 | 0.60 | 120 | 0.51 | 102 | 0.44 | 88 |
| Riboflavin (mg) | 0.80 | 0.50 | 63 | 0.61 | 76 | 0.58 | 73 |
| Niacin (mg) | 9.0 | 5.6 | 62 | 6.6 | 73 | 6.3 | 70 |
| Folate (μg) | 50 | 127 | 254 | 153 | 306 | 122 | 244 |
| Vitamin B6 (mg) | 1.0 | 1.1 | 110 | 0.6 | 60 | 0.6 | 60 |
| Vitamin B12 (μg) | 0.50 | 0.08 | 16 | 1.72 | 344 | 1.85 | 370 |
| Pantothenate (mg) | 3.0 | 1.8 | 60 | 2.2 | 73 | 1.8 | 60 |
| Vitamin E (mg TE) | 6.0 | 2.7 | 45 | 4.5 | 75 | 3.1 | 52 |
| Vitamin D (μg)[3] | 10.0 | 0.5 | 5 | 0.6 | 6 | 1.5 | 15 |
| Dietary Fiber (g) | --- | 21 | --- | 14 | --- | 14 | --- |
| Phytate (mg) | --- | 837 | --- | 626 | --- | 1314 | --- |
| Phytate: zinc molar ratio[4] | --- | 26 | --- | 13 | --- | 27 | --- |

[1] Kenya sample = cluster 1; Egypt sample = first 20%; Mexico sample = community 2

[2] Rec = recommendations summarized in Wood-Dahlstrom and Calloway, 1990; and U.S. NRC, 1989 when there is no international recommendation. Iron and zinc recommendations adjusted for low availability. Copper and pantothenate recommendations are the minimum safe and adequate level.

[3] 1 μg Vitamin D = 30 IU.

[4] (Phytate (mg)/(660)/(zinc (mg)/65.4)

associated with clinical or chemical evidence of zinc deficiency (Oberleas and Harland, 1981).

Dietary fiber intakes also are high in all three countries, ranging from 14 grams per day for Egypt and Mexico toddlers to 52 grams per day for Kenya lead females. By comparison, young women in the U.S. have estimated intakes of 13 grams of dietary fiber per day, 395 mg of phytate per day, and a phytate:zinc ratio of 5.8 (Murphy and Calloway, 1986).

Iron intakes also were low, particularly for lead females and toddlers, as well as for schoolers in Mexico. As with zinc, the recommended levels of intake have been adjusted to assume low bioavailability due to the lack of animal-source iron in the diets. Chronically low intakes of iron are associated with anemia, and its potential functional consequences which include impaired work performance in adults and reduced learning ability in children.

Vitamin B12 intakes appear to be seriously low (less than 20% of recommendations) in Kenya. If these intake estimates are correct, macrocytic anemia should be common among this population; the Kenya Project reports macrocytic anemia in 6 to 9% of lead females, 3% of schoolers, and 8 to 12% of toddlers (Neumann and Bwibo, 1987). It is also possible that sources of vitamin B12 in the Kenya diet have been overlooked, e.g., fermented food products or insects. Calcium intakes also appear to be very low in the Kenya diet, with toddlers at only 33% of the recommendation. Although low calcium intakes may be partially compensated by increased absorption, it is of concern that growing children and reproductively active women's intakes are substantially below those considered adequate.

Other nutrients appear to be low for selected populations. Vitamin A intakes may be marginal for children in Mexico (with possible implications for respiratory infections and vision disorders), while vitamin E is low for all age groups in Mexico (although the clinical significance is difficult to estimate, long-term low intakes may be associated with increased susceptibility to oxidant stress). In addition to vitamin B12, other B-vitamins may be low in diets of schoolers and toddlers: thiamin for Mexico schoolers, riboflavin for Kenya schoolers and toddlers and Mexico schoolers, niacin for Kenya toddlers, vitamin B6 for Mexico schoolers and toddlers and Egypt toddlers, and pantothenic acid for Mexico schoolers and toddlers and Kenya toddlers. Selected signs of B-vitamin deficiency have been reported by all three projects, with implications for growth and developmental disorders.

As shown in Tables 1-3, other nutrients not mentioned above may be marginal in selected diets. Even where mean intakes are above 70% of recommendations, there is the possibility of deficiency for specific individuals. Further analytic work is required to consider the distribution of both intakes and requirements and then estimate an overall risk of deficiency for each nutrient by age and country.

To investigate protein quality, the dietary level of 9 essential amino acids was calculated. Kenya reported the lowest intake of animal foods of the three countries, and toddlers have a higher requirement of protein per kilogram of body weight than schoolers or adults. Thus, Kenya toddlers are likely to be a group at risk for protein inadequacy, and are used to illustrate the calculations performed. Table 4 shows the estimated requirement of each amino acid, using

TABLE 4 (Preliminary)
Comparison of essential amino acids requirements and intakes of Kenya toddlers (cluster #1)

| Essential Amino Acid | FAO/WHO/UNU Requirement[1] mg/kg | KENYA TODDLER, 10.5 kg Requirement, mg/day Absorbed | Diet[2] | Observed Intake Intake mg/d | % of requirement |
|---|---|---|---|---|---|
| Histidine | 21 | 220 | 268 | 575 | 215 |
| Isoleucine | 31 | 325 | 396 | 784 | 198 |
| Leucine | 73 | 766 | 934 | 1828 | 196 |
| Lysine | 64 | 672 | 820 | 891 | 109 |
| Meth+cys | 27 | 284 | 346 | 631 | 182 |
| Phen+tyr | 69 | 724 | 883 | 1620 | 183 |
| Threonine | 37 | 388 | 473 | 730 | 154 |
| Tryptophan | 12.5 | 131 | 160 | 193 | 121 |
| Valine | 38 | 399 | 487 | 998 | 205 |

[1]From FAO/WHO/UNU, 1985, Table 4 (p. 65).
[2]Assuming 82% digestibility.

TABLE 5 (Preliminary)
FAO/WHO/UNU Pattern of essential amino acid requirements and intake pattern of a sample of Kenya toddlers and schoolers (cluster #1)

| Amino Acid | Toddlers mg/g crude protein Requirement[1] | Intake | Score % | Schoolers mg/g crude protein Requirement[1] | Intake | Score % |
|---|---|---|---|---|---|---|
| Lysine | 58 | 46 | 79 | 44 | 46 | 100 |
| Meth+Cys | 25 | 33 | 100 | 22 | 33 | 100 |
| Threonine | 34 | 38 | 100 | 28 | 39 | 100 |
| Tryptophan | 11 | 10 | 91 | 9 | 9 | 100 |

[1]From FAO/WHO/UNU, 1985, Table 38 (p. 121).

the FAO/WHO/UNU requirements (FAO/WHO/UNU, 1985). The requirements are given in milligrams per kilogram, and are then multiplied by the average body weight of a Kenya male toddler (10.5 kg). This amount is adjusted for an estimated 82% digestibility, to give the dietary requirement. The average diet of a Kenya toddler exceeded the requirements for all amino acids. Lysine intakes were lowest as a percent of requirement (109%) followed by tryptophan (121%).

The safe level of dietary protein was calculated for schoolers and toddlers, based on the most limiting amino acid in the average diet. Table 5 illustrates the calculation of the amino acid scores for Kenya schoolers and toddlers (for 4 amino acids), to determine the limiting amino acid ((FAO/WHO/UNU, 1985). For toddlers, lysine was the most limiting, with a score of 79% compared to a reference protein. As shown in the table, there were no limiting amino acids for Kenya schoolers. For Mexico toddlers the amino acid score was 93% (lysine and tryptophan were equally limiting); there were no limiting amino acids for Mexico schoolers or for Egypt schoolers or toddlers.

FAO/WHO/UNU recommends 1.15 grams of reference protein per kilogram per day for toddlers and 1.01 g/kg/d for schoolers - the mean requirement plus 2 standard deviations. Table 6 compares observed intakes with estimated safe levels of dietary protein (the safe level of reference protein adjusted upward for assumed digestibility and protein score). Thus, 1.15 grams reference protein per kilogram per day for toddlers, adjusted upward for a score of 79% and a digestibility of 82%, becomes a recommendation of 1.78 grams dietary protein per kilogram per day for Kenya toddlers. Actual (observed) protein intake of Kenya toddlers was 1.83 g/kg/d, which is just above the recommended intake.

These same calculations may be repeated for Kenya schoolers. A recommended intake of 1.01 g/kg/d is adjusted upward for 82% digestibility to give 1.22 g/kg/d (no adjustment for quality is necessary since there were no limiting amino acids). At 2.04 g/kg/d, intakes are well above the safe level. Thus, even after adjustment for quality and digestibility, mean protein intakes for Kenya toddlers (103% of safe level) and schoolers (166% of safe level) appear adequate. Protein levels in Mexico were well above the safe level (200% for toddlers and 183% for schoolers), and even higher in Egypt (217% for toddlers and 222% for schoolers). However, even though mean intakes appear adequate, it is likely that diets of some individuals are at risk of deficiency. Further analyses are required to estimate the overall risk of protein deficiency for each of the three countries.

<u>Implications</u>

Even though the trends reported above are likely to be a valid representation of the full data sets, the results of these analyses must be considered preliminary. Additional analyses are urgently needed to confirm the following implications:

Diets in all three countries meet the FAO/WHO/UNU safe levels of protein on the average, although selected individuals are likely to be at risk of protein deficiency during at least some period of observation. Interventions based on increasing protein quality or quantity as an isolated issue cannot be justified based on these analyses. Additional analyses of these data are needed to better estimate the overall risk of protein deficiency for each age category in each country over time.

**Table 6 (Preliminary)**
**Observed protein intakes of a sample[1] of toddlers and schoolers compared to FAO/WHO/UNU recommended safe levels of intake (mean requirement + 2 SD)**

| | Toddlers | Schoolers |
|---|---|---|
| FAO/WHO/UNU[2] | | |
| safe level of reference protein | 1.15 g/kg/d | 1.01 g/kg/d |
| Egypt: | | |
| assumed digestibility[3] | 90% | 90% |
| protein (EAA) score[4] | 100% | 100% |
| safe level of dietary protein[5] | 1.28 g/kg/d | 1.12 g/kg/d |
| observed intake[6] | 2.78 g/kg/d | 2.49 g/kg/d |
| % of safe level | 217% | 222% |
| Kenya: | | |
| assumed digestibility[3] | 82% | 82% |
| protein (EAA) score[4] | 79% | 100% |
| safe level of dietary protein[5] | 1.78 g/kg/d | 1.23 g/kg/d |
| observed intake[6] | 1.83 g/kg/d | 2.04 g/kg/d |
| % of safe level | 103% | 166% |
| Mexico: | | |
| assumed digestibility[3] | 88% | 88% |
| protein (EAA) score[4] | 93% | 100% |
| safe level of dietary protein[5] | 1.41 g/kg/d | 1.15 g/kg/d |
| observed intake[6] | 2.82 g/kg/d | 2.10 g/kg/d |
| % of safe level | 200% | 183% |

[1]Egypt sample - First 20%; Kenya sample - Cluster 1; Mexico sample - Community 2.
[2]FAO/WHO/UNU safe level of protein from FAO/WHO/UNU, 1985, Table 33 (p. 105). Toddler level is average of 1.5 - 2 yr and 2 - 3 yr.
[3]Digestibility is estimated from FAO/WHO/UNU, 1985, Table 36 (p. 119). Egypt: wheat, whole; Kenya: maize + beans; Mexico: maize + beans + milk.
[4]Protein (essential amino acid) scores are calculated from the amino acid profile of the diet compared to FAO/WHO/UNU, 1985, Table 4, p. 65).
[5]Calculated as 1.15/dig/score for toddlers and 1.01/dig/score for schoolers.
[6]Calculated using weights from Calloway et al, 1988, Table 5 (p. 31) (male or female weight, whichever is larger).

The Kenya population would benefit from interventions which make more of the same diet available to all individuals. This population is probably at risk of low protein/calorie intakes, a potential cause of stunting and decreased cognitive performance in children. Adult intakes also are marginal in quantity, as is also demonstrated by low body mass indexes and the lack of an increase in BMI with age for women.

The bioavailability of nutrients in all three countries is low due to high intakes of dietary fiber, especially in Kenya. Phytate in diets also is high in Kenya and Mexico, leading to particular concerns about the availability of dietary zinc. Processing methods which reduce phytate (such as yeast-leavening of bread) or dietary fiber (such as partial refinement of certain grains) might be appropriate.

Levels of several nutrients known to be necessary for normal functions are marginal to very low in many diets. Vitamin B12 and calcium are low in the diets of Kenyans, while iron and zinc are low in all diets. Numerous other nutrients are low for selected age groups or specific countries. Food sources of these nutrients need to be identified so their use can be promoted.

A high priority should be given to identification of the characteristics of diets (in all three countries) with adequate levels of nutrients but without very high levels of fiber and phytate. It is likely that such diets will be relatively higher in animal-source foods. Once described, these diets would serve as a potential model for education and intervention efforts, both within these countries and for other countries as well.

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# II. RELATION OF MATERNAL DIETARY QUALITY TO INFANT BEHAVIOR AND INFANT-CAREGIVER INTERACTIONS IN EGYPT

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## Part 1. Maternal Dietary Quality and Neonatal Behavior

Systematic and quantifiable methods of assessing neonatal behavior allow for an extension of the understanding of perinatal events beyond infant mortality and major physical and/or mental handicapping conditions. Assessment of the neonate in an interactive process by use of an instrument such as the Brazelton Neonatal Assessment Scale (BNAS) tests the infant's coping and adaptive strategies in response to external stimuli and manipulations. Thus the neonate is observed as part of a feedback system in which he or she affects and is affected by the environment. Previously vitamin B-6 status of mothers in the Egypt project was found to significantly affect the ability of newborns to integrate their adaptive responses over the first few days after birth (Appendix A). The present study examined in the same population the relation of dietary quantity and/or quality during gestation to the behavioral organization of the neonate.

### Methods

Pregnant women eligible for the study were between 17 and 45 years of age and in the first trimester of their pregnancy. A total of 63 women completed most parts of the study. Upon entry into the study, all women underwent a medical history interview and a general physical examination in their homes. The medical history included information on disabilities and chronic illnesses as well as the past 6-month history of common illnesses including diarrhea, respiratory and urinary tract infections. A reproductive history questionnaire was completed to obtain information about age, parity, fetal deaths and number of living and dead children. Illness experience was documented by a weekly recall during the course of pregnancy. All anthropometric measurements were performed by a team of physicians beginning prior to or at the 3rd month of pregnancy. Measurements were scheduled to be performed monthly up to the 8th month and then weekly until delivery. The general methodologic approach to food intake measurement combined probed oral self-report and sample weighing to obtain data on individual food and beverage intakes during two consecutive days monthly starting from the 3rd month of gestation.

The BNAS, Kansas Supplement was the instrument used to assess the behavioral organization and development of the neonates in an interactive situation with the examiner. Currently the BNAS is among the most widely used instruments for assessing neonatal behavioral status. This test includes the assessment of neurological items but focuses on behavioral items which measure the infant's responses to various stimuli that elicit coping and adaptive strategies. The test was administered to all neonates by an Egyptian child psychiatrist who was trained to reliability in scoring at the University of Kansas. The tests were administered to 70% of the infants between 3 and 5 days after birth and to all infants by day 7.

**Characteristics of the Sample**

Mean age of the pregnant women was 26.1±6.1 years, and most (60.3%) were between the ages of 20 to 30 years. Mean parity was 4.0±2.6 and only 6.3% of the study population was primigravid. Almost one-fourth of the women (20.6%) reported seven or more previous pregnancies. Most women had little or no formal education. Among those who had received formal education, only 11% exceeded six years and only 12% were literate. About two-thirds of the study population households were classified as low or low intermediate SES. Household sanitation indices were significantly higher for the high and upper intermediate SES groups indicating better sanitation than for the two lower SES categories.

**Anthropometry**

Women were generally short in stature (mean of 155.3±5.0 cm) and normal to over-weight (mean of 61.0±10.3 kg) in early pregnancy (Table 1). Mean body mass index (BMI) in early pregnancy was 25.2±4.0; approximately two-thirds of the women were in the normal BMI range of 19.8-26.0 and one-third were overweight or obese (>26.0 BMI). Mean weight gain during the last 6 months of pregnancy of 7.7±3.2 kg was considerably less than gains of 12.5 kg or more, generally reported for pregnent women in developed countries. Almost one-third of the women gained less than 6.0 kg. Arm circumference measurements, biceps and triceps skinfold thicknesses, essentially did not change during the last 6 months of pregnancy.

TABLE 1
Mean and frequency distribution of maternal anthropometry (n=63)

| | | | **Body mass index*** | | |
|---|---|---|---|---|---|
| | Underweight | Normal | Overweight | Obese | |
| Mean ± SD | <19.8 | 19.8-26.0 | 26.0-29.0 | ≥29.0 | |
| | | | % of mothers | | |
| 25.2 ± 4.0 | 1.6 | 64.5 | 21.0 | 12.9 | |
| 19.6 - 37.0† | (2)‡ | (40) | (13) | (8) | |
| | | | **Early pregnancy weight, kg** | | |
| Mean ± SD | <50 | 50-60 | 60-70 | ≥70 | |
| | | | % of mothers | | |
| 61.0 ± 10.3 | 11.1 | 47.6 | 23.8 | 17.5 | |
| 44.8 - 92.4† | (7)‡ | (30) | (15) | (11) | |
| | | | **Pregnancy weight gain, 3-9 mo, kg** | | |
| Mean ± SD | <3 | 3-6 | 6-9 | 9-12 | ≥12 |
| | | | % of mothers | | |
| 7.7 ± 3.2 | 4.8 | 26.9 | 39.7 | 14.3 | 14.3 |
| 2.6 - 15.4 | (3) | (17) | (25) | (9) | (9) |

*Body weight (kg)/height ($cm^2$).
†Range.
‡Number of subjects.

**Food Intake**

Mean energy intake during the last two trimesters of pregnancy was 2055 kcal/day and ranged from 1099-2888 (Table 2). During this period, 9.1% of the women had mean intakes of less than 1500 kcal/day and 10.9% exceeded 2500 kcal/day. Three-fourths of the study group consumed 80% or more of their energy from plant foods; the mean percent of energy from animal foods was 16.5% and 40% had less than 15% from animal sources. More than 90% of the women studied consumed 12% or more of their daily energy intake as protein. Mean total protein intake was about 66 g/day and almost two thirds of the women (62.0%) consumed 60 g/day or more. During the last 6 months of pregnancy, mean animal protein intake comprised approximately 23 g (range, 2 to 41 g) of the total daily protein intake and plant protein about 43 g (range, 25 to 64 g). Mean fat intake was 56.5 g/d and was equally divided among animal and plant sources.

TABLE 2
Mean and frequency distribution of energy and protein intakes during 3 to 9 months of pregnancy (n=55)

| | | | | | |
|---|---|---|---|---|---|
| | | | **Energy, kcal/d** | | |
| **Mean ± SD** | **<1500** | **1500-2000** | **2000-2500** | **≥2500** | |
| | | | % of mothers | | |
| 2055 ± 402 | 9.1 | 34.5 | 45.5 | 10.9 | |
| 1099 -2888* | (5)† | (19) | (25) | (6) | |
| | | | **Energy, % kcal from animal sources** | | |
| **Mean ± SD** | **<10** | **10-15** | **15-20** | **20-25** | **≥25** |
| | | | % of mothers | | |
| 16.5 ± 5.5 | 9.1 | 30.9 | 34.5 | 20.0 | 5.5 |
| 2.5 -30.4 | (5) | (17) | (19) | (11) | (3) |
| | | | **Energy, % kcal from plant sources** | | |
| **Mean ± SD** | **<75** | **75-80** | **80-85** | **85-90** | **≥90** |
| | | | % of mothers | | |
| 83.5 ± 5.5 | 5.5 | 20.0 | 34.5 | 30.9 | 9.1 |
| 70.0 -97.5 | (3) | (11) | (19) | (17) | (5) |
| | | | **Total protein, g/d** | | |
| **Mean ± SD** | **<50** | **50-60** | **60-70** | **70-80** | **≥80** |
| | | | % of mothers | | |
| 65.8 ±14.0 | 12.7 | 25.5 | 25.4 | 14.6 | 21.8 |
| 35.8 -96.5 | (7) | (14) | (14) | (8) | (12) |
| | | | **Animal protein, g/d** | | |
| **Mean ± SD** | **<15** | **15-20** | **20-25** | **25-30** | **≥30** |
| | | | % of mothers | | |
| 23.0 ± 8.8 | 16.4 | 30.9 | 14.5 | 12.7 | 25.5 |
| 2.4 -41.2 | (9) | (17) | (8) | (7) | (14) |
| | | | **Plant protein, g/d** | | |
| **Mean ± SD** | **<35** | **35-40** | **40-45** | **45-50** | **≥50** |
| | | | % of mothers | | |
| 42.8 ± 9.7 | 27.3 | 18.2 | 14.5 | 10.9 | 29.0 |
| 24.6 -64.0 | (15) | (10) | (8) | (6) | (16) |

*Range.
†Number of subjects.

Neonatal Behavioral Assessment

Among 27 neonatal behavior items assessed by the BNAS within the first 7 days following birth, several responses were associated with early pregnancy weight, body mass index and/or food intake of the mother during pregnancy (Tables 3 and 4). For example, early pregnancy weight was significantly

TABLE 3
Relation of maternal and infant anthropometry and gestational age to neonatal behavioral characteristics

| Brazelton Neonatal Assessment Scale (selected items) | Mother: Body mass index | Mother: Early pregnancy weight | Infant: Gestational age | Infant: Birth weight | Infant: Weight gain 0-3 mo |
|---|---|---|---|---|---|
| | n=38 | n=39 | n=42 | n=53 | n=48 |
| **Habituation** | **Pearson correlation coefficient, r** | | | | |
| Bell | | | 0.382[a] | | |
| **Orientation** | | | | | |
| Inanimate visual | 0.348[a] | 0.398[a] | | | 0.357[a] |
| Inanimate auditory | | 0.282[a] | 0.328[a] | | |
| Inanimate visual-auditory | 0.429[b] | 0.451[b] | | | |
| Animate visual | | | 0.317[a] | | |
| Animate auditory | | | | | 0.389[a] |
| Animate visual-auditory | | 0.318[a] | | | 0.318[a] |
| Alertness | | | 0.335[a] | | |
| **Motor Performance** | | | | | |
| Defense | | | 0.307[a] | | |
| **Range of State** | | | | | |
| Rapidity of buildup | | | | 0.258[a] | |
| Irritability | | | 0.342[a] | | |
| **Regulation of State** | | | | | |
| Consolability | | | | 0.357[b] | |
| Self-quieting | 0.321[a] | 0.316[a] | | | |
| Hand to mouth | | | | 0.373[b] | 0.263[a] |
| **Autonomic Stability** | | | | | |
| Skin color | | | | 0.291[a] | |
| **Reflexes** | | | | | |
| Incurvature | | | 0.499[c] | | |
| Crawling | | | 0.348[a] | | |
| Glabella | | | 0.355[a] | | |
| Tonic deviation of head and eyes | | | 0.361[a] | | |
| Resistance - arms | | | | | 0.324[a] |
| **Supplementary Items** | | | | | |
| Quality of response | 0.318[a] | 0.296[a] | 0.321[a] | | |
| Response to examiner | | | 0.464[b] | | |
| **Clusters*** | | | | | |
| Orientation | | 0.325[a] | | | |
| Reflex | | | 0.404[b] | | |

*Organization of data that are conceptually and empirically based.
[a]$p<0.05$; [b]$p<0.01$; [c]$p<0.001$.

TABLE 4
Relation of dietary quality during pregnancy to neonatal habituation behavior and of early pregnancy weight to neonatal orientation behavior

| Independent variable | Regression coefficient ±SE | p | $R^2$ |
|---|---|---|---|
| (n=45) **Dependent variable: Neonatal habituation behavior*** | | | |
| Energy intake from animal sources, kcal/d | 0.002 ± 0.0008 | 0.008 | 0.15 |
| Intercept | 4.90 ± 0.318 | | |
| Energy intake from animal sources, % kcal/d | 0.052 ± 0.022 | 0.02 | 0.12 |
| Intercept | 4.818 ± 0.397 | | |
| Animal protein intake, g/d | 0.028 ± 0.013 | 0.03 | 0.10 |
| Intercept | 5.031 ± 0.0001 | | |
| Animal fat intake, g/d | 0.026 ± 0.009 | 0.009 | 0.15 |
| Intercept | 4.959 ± 0.299 | | |
| Total energy, kcal/d | | NS | |
| Total protein, g/d | | NS | |
| SES | | NS | |
| (n=34) **Dependent variable: Neonatal orientation behavior†** | | | |
| Early pregnancy weight (3 mo), kg | 0.015 ± 0.007 | 0.03 | 0.13 |
| Intercept | 5.494 ± 0.421 | | |
| Total energy, kcal/d | | NS | |
| Energy intake from animal sources, kcal/d or % kcal/d | | NS | |
| Total protein, g/d | | NS | |
| Animal protein, g/d | | NS | |
| SES | | NS | |

*Cluster of four items of habituation behavior.
†Cluster of seven items of orientation behavior.

related to the orientation behavior cluster. This cluster of seven orientation items measures the global responses of neonates to animate and inanimate visual and/or auditory stimuli. Both early pregnancy weight and BMI of the mother were significantly related to the neonate's ability to regulate state by self-quieting and to the quality of the infant's response to the examiner. Birth weight of the neonate was positively related to his or her rapidity of build-up to an upset state, consolability and skin color changes during the assessment. Gestational age of the infant was associated positively with several orientation items, reflexes and irritability (Table 3).

Maternal food intake during pregnancy was significantly associated with neonatal habituation behavior (Table 4). Habituation, measured by decrement of response to sound (rattle and bell), was positively related to the mother's dietary quality during pregnancy. Maternal intakes of energy from animal sources (expressed as kcal/d or % kcal/d), animal protein or fat intake, g/d were significantly associated with the habituation cluster of four stimuli (rattle, bell, light and pin-prick). When 18 maternal, infant and household variables (Table 5) were included in multiple regression analysis for the prediction of neonatal habituation behavior, the prediction was not improved over that of simple regression with maternal dietary quality factors included as the independent variables ($R^2$=0.15).

TABLE 5
Independent variables considered as candidate predictors of neonatal behavior

**Maternal variables**
- Age
- Education, years
- Parity
- Previous birth interval
- Number of fetal deaths
- Number of live children
- Height
- Weight at 3 months of pregnancy (kg, body mass index, % ideal weight for height)
- Weight gain, 3 to 9 months of pregnancy, kg
- Length of gestation, wk
- Food intake (kilocalories; kilocalories from animal and plant foods; animal and plant protein; and animal and plant fat across the second and third trimesters of pregnancy)
- Percentage of time sick
- Percentage of time sick excluding skin ailments

**Household variables**
- Socioeconomic status
- Sanitation-hygiene index
- Infant/child mortality

**Infant variables**
- Birth weight
- Infant weight, 3 mo

Implications of the Findings

The Brazelton Neonatal Assessment Scale used in this study is based on an interactive process for assessment of the infant's capacity to control his or her physiological system in response to external manipulations. A well-organized neonate has the capacity to control levels of stimulation by the use of state (from sleep to alertness) whereas some neonates have a low threshold for stimuli (hypersensitivity) or a disorganized response to stimuli. The disorganized infant may be difficult for his caretaker and is at risk of neglect or abuse in certain environments. Some investigators have postulated that the most important predictor of the infant's integrity may be the infant's capacity to integrate his or her responsive behavior over the first few days of life.

Habituation is a behavioral process which describes the ability of the infant to respond to and then inhibit responding to a discrete stimulus or even to shut out a disturbing stimulus (light, rattle, bell, pin-prick) while asleep. In this study, the quality of the mother's diet during trimesters 2 and 3 of pregnancy, expressed either as kcal/d or as % kcal/d from animal sources, or as animal protein (g/d), was positively related to habituation behavior of the neonate.

Food intake from animal products is possibly an important marker of the mother's nutritional status which in turn influenced neonatal behavior. To determine whether this is related to specific nutrients present in animal products, to nutrients which are more bioavailable from animal foods or to a better overall dietary pattern when animal products are included in the diet will require further study. A detailed analyses is needed of the dietary constituents that underlie these observations.

In contrast to habituation, orientation behavior includes the quality of the alert state and the ability of the neonate to respond to visual and auditory stimuli while alert. The orientation cluster comprised of seven items measures primarily attentional performance. The importance of orientation behavior is emphasized by the belief that it is an important shaper of the infant's nurturing environment. The ability of the infant to orient to both auditory and visual stimuli in the immediate neonatal period was significantly influenced by early pregnancy weight of the mother whereas food intake of the mother during pregnancy was not significantly related to orientation behavior. The basis of the positive influence of early pregnancy weight on orientation behavior of the neonate is possibly that early pregnancy weight was a marker of the mother's nutritional status.

These results relating neonatal behavior to maternal nutrition and health are emphasized by the findings that neither literacy of the mother or father, type of occupation of the father, socioeconomic status of the household or household sanitation index were significantly related to neonatal behavioral organization. Furthermore, maternal morbidity (% of time sick with all illnesses and % of time sick with all illnesses excluding skin ailments) was not associated with neonatal behavior, either directly or indirectly through its relationship to age, anthropometry or household SES.

<u>Summary and Conclusions</u>

Among the many variables which were examined, only early pregnancy weight and maternal dietary quality were related significantly to neonatal behavioral organization. Energy from animal source foods (kcal/d or % kcal) appeared to be a marker of dietary quality. Whether this was related to specific nutrients present in animal source foods, to nutrients which were more bioavailable or to a better overall dietary pattern when animal source foods were included remain to be elucidated. Quality, but not quantity, of the mother's diet during pregnancy related positively to habituation behavior of her infant during the first few days after birth whereas early pregnancy weight was related to neonatal orientation behavior. These preliminary results require further refinement but they illustrate the complex synergistic relations between neonatal behavior and certain variables related to maternal health, i.e. early pregnancy weight and dietary quality during pregnancy. The

findings emphasize the importance of weight monitoring, prior to pregnancy as well as during the course of pregnancy, as a marker for appropriate medical and nutritional counseling. An important next step in data analysis is to identify characteristic food group profiles of maternal diets which appear to support desirable neonatal behavioral outcomes. Such information is critical to nutrition education and intervention programs for women, designed to improve their nutrition and their pregnancy outcomes.

## Part 2. Relation of Maternal Dietary Characteristics to Infant-Caregiver Interactions and Infant Behavior at 3 to 6 Months of Age

Under conditions where infants are nutritionally at risk and where infant care and medical attention are far below optimal, infant morbidity may be one of the factors resulting in impaired developmental outcomes. Repeated illnesses of the infant may be associated with reduced food intake and inactivity, which in turn adversely affects the infant's relationship with the environment. These infants may fail to take advantage of or respond to learning situations which eventually lead to deficits in their cognitive performance. Under such circumstances, infants may need more attention and stimulation from their mothers/caregivers. Yet a caregiver who is also malnourished may be incapable of providing the extra care needed by the at-risk infant. Thus, the synergistic effects of malnutrition of the infant and that of the mother/caregiver can hamper both the physical and cognitive growth of the infant. This study was an exploratory examination in Kalama village of the relation of maternal dietary quantity and/or quality during lactation to infant morbidity and behavior and to caregiver/infant interactions from 3 to 6 months of age.

### Methods

Among the mother-infant pairs who participated in the neonatal behavior study, (discussed previously), complete food intake data were available for 42 mothers during the first 6 months of lactation. Also, anthropometry and morbidity data were available for the majority of their infants. These 42 mother-infant pairs comprised the study population for most analyses. Procedures for anthropometric measurements, food intake estimation and morbidity documentation were the same as those described previously for the neonatal behavioral study.

Caregiver/infant interaction and infant behavior were documented by trained field workers. Naturalistic observations of infants were made in village homes twice monthly during 3 to 6 months of age. During each 30 minute observation, observers recorded the number of caregiver's vocalizations, the number and duration of physical contact, the caregiver's verbal responsiveness to the infant's vocalizations, and the caregiver's response to child distress. After each 5 minutes of observation, the observer recorded the number of people in the home, the designated caregiver, whether mother was within reach of the infant, the infant's location, the amount of the infant's social and object involvement and the characteristic state of the infant (i.e. from drowsy to irritable). Interobserver agreement obtained during the course of the study was found to be satisfactory (mean = 0.93, range = 0.58-1.00).

Infant State and Behavior

Among all of the infant state and behavioral variables examined (Table 1), degree of drowsiness (a state variable) was most influenced by the quality of the mother's diet. Drowsiness was assessed only in infants who were awake and who had not been sick within the past three days. Drowsiness was defined by a specified set of behavioral criteria, including activity level of the infant and whether the infant's eyes, if open, were focusing on an object or person in the environment. Infants were categorized as non-drowsy, mildly drowsy (1-10%/time) and very drowsy (more than 10%/time) (Table 2). The analytic questions addressed were: Is the quantity and/or quality of the maternal diet associated with the degree of infant drowsiness? Are other variables related?

TABLE 1
Caregiver/infant interaction and infant state and behavior variables

**Caregiver/infant interaction**

- Responsible caregiver (% time): parent, grandparent, adult relative or sib
- Infant location
- Mother or caregiver within reach of infant (% time)
- Response to infant's distress (% time): effective, noneffective or no response
- Response to infant's vocalization (% time): verbal, nonverbal or no response
- Number of spontaneous vocalizations to infant
- Physical contacts with infant: number and duration

**Infant state and behavior**

- State rating: 4 point code from drowsy to irritable (% time)
- Number and duration of distress
- Number of spontaneous vocalizations
- Involvement with objects/people (% time)

Mothers of very drowsy infants had less total energy intakes and less energy from animal sources; they also had lower intakes of total and animal protein, of total and animal iron and lower intakes of some vitamins than mothers of non-drowsy infants (Table 2). By simple regression analysis, total energy intake of the mother and energy intakes from animal and plant sources were significantly and inversely related to infant drowsiness (Table 3). Energy intake from animal source foods (kcal/d), however, was the most significant and powerful single predictor of infant drowsiness. Multiple regression analysis indicated that the combination of total energy intake and energy from animal sources was the best predictor model of infant drowsiness, $R^2$=0.35 (Table 3). Clearly, maternal dietary quantity as well as quality contributed to a more appropriate infant state i.e. a more alert infant.

Morbidity

In general, Kalama infants experienced a heavy burden of illnesses; diarrhea and respiratory tract infections were reported in 20-25% of the infants during the first 3 months and in 35-40% during 3 to 6 months. When all illnesses

TABLE 2
Relation of certain household and maternal variables to infant drowsiness

| Variables | Infant drowsiness, % time 0 | >0-10 | >10-24 | p* |
|---|---|---|---|---|
| **Household** | (n=19) | (n=16) | (n=12) | |
| Socioeconomic status† | 2.37± 1.16 | 1.94± 0.77 | 1.75± 0.62 | NS |
| **Mother** | | | | |
| Age, yrs | 24.2 ± 4.5[a] | 25.5 ± 5.9[a] | 31.0 ± 6.8[b] | 0.002 |
| Parity | 3.84± 2.71[a] | 3.50± 1.97[a] | 6.08± 3.70[b] | 0.06 |
| No. of live children | 2.32± 1.38[a] | 2.62± 1.36[ab] | 3.58± 1.56[b] | 0.02 |
| Food intake, 0-6 mo | | | | |
| Energy, kcal/d | (n=18) | (n=14) | (n=10) | |
| Total | 2318± 320[a] | 2244± 311[a] | 1951± 214[b] | 0.003 |
| Animal source | 413± 104[a] | 386± 139[a] | 255± 98[b] | 0.0006 |
| Plant source | 1920± 305 | 1875± 298 | 1714± 158 | 0.03 |
| % from animal sources | 17.8 ± 4.6[a] | 17.1 ± 5.7[a] | 12.8 ± 4.2[b] | 0.008 |
| Protein, g/d | | | | |
| Total | 75.2 ±10.2[a] | 69.6 ±10.2[ab] | 61.9 ±10.5[b] | 0.003 |
| Animal | 27.4 ± 7.1[a] | 23.5 ± 7.5[ab] | 18.0 ± 8.0[b] | 0.003 |
| Plant | 47.8 ± 7.5 | 46.1 ± 8.1 | 43.9 ± 5.8 | NS |
| Iron, mg/d | | | | |
| Total | 17.6 ± 2.7[a] | 16.8 ± 2.7[ab] | 15.2 ± 3.4[b] | 0.05 |
| Animal | 3.77± 1.83[a] | 2.87± 1.21[ab] | 1.87± 1.32[b] | 0.008 |
| Plant | 13.8 ± 1.7 | 13.9 ± 2.2 | 13.3 ± 2.8 | NS |
| Vitamin A, RE/d | 618± 256 | 638± 220 | 452± 267 | NS |
| Vitamin C, mg/d | 109± 38[a] | 109± 38[ab] | 78± 33[b] | 0.04 |
| Thiamin, mg/g | 1.33± 0.18 | 1.29± 0.21 | 1.20± 0.16 | 0.08 |
| Riboflavin, mg/d | 1.35± 0.26[a] | 1.26± 0.16[b] | 1.02± 0.21[b] | 0.002 |
| Niacin, mg/d | 14.2 ± 2.4[a] | 12.4 ± 2.9[ab] | 10.8 ± 3.1[b] | 0.004 |

*Two group comparison: 0 and >10% time drowsy (t-test).
†1=low, 4=high.
[ab]Three group comparison by least squared difference; means with different superscripts are significantly different ($p<0.05$).

were included in the analysis, 93% of the infants were reported to be ill between birth and 6 months and one fourth of them were sick more than 20% of the time. Diarrheal illnesses of infants were inversely related to household sanitation index and SES. The group of very drowsy infants were sick more often with diarrhea, showed a higher number of distress episodes and tended to be less involved with people and objects than non-drowsy infants (Table 4). These infants also received less vocalization from their caretakers and tended to receive more non-effective response to their distress from caregivers compared to infants who were not drowsy.

TABLE 3
Relation of maternal dietary quantity and quality to infant drowsiness

| Independent variables | Regression Coefficient ±SE | p | $R^2$ |
|---|---|---|---|
| | **Dependent variable: Infant drowsiness** | | |
| | **Simple regressions (n=42)** | | |
| Energy intake, 0-6 mo | | | |
| Total, kcal/d | -0.010 ± 0.003 | 0.001 | 0.24 |
| Intercept | 28.7 ± 6.5 | | |
| Animal source, kcal/d | -0.027 ± 0.007 | 0.0004 | 0.27 |
| Intercept | 16.2 ± 2.77 | | |
| Plant source, kcal/d | -0.008 ± 0.004 | 0.04 | 0.10 |
| Intercept | 20.4 ± 6.8 | | |
| % from animal sources | -0.532 ± 0.189 | 0.008 | 0.16 |
| Intercept | 14.9 ± 3.25 | | |
| | **Multiple regressions (n=42)** | | |
| Energy intake | | | |
| Animal source, kcal/d | -0.026 ± 0.007 | 0.0006 | 0.33 |
| Plant source, kcal/d | -0.006 ± 0.003 | 0.06 | |
| Intercept | 27.2 ± 6.2 | | |
| Total, kcal/d | -0.009 ± 0.003 | 0.002 | 0.35 |
| % from animal sources | -0.458 ± 0.170 | 0.01 | |
| Intercept | 34.2 ± 6.4 | | |

Predictors of Infant Drowsiness

Among all variables examined (Table 5), maternal dietary quality, i.e., energy intake from animal sources was the most significant predictor of infant drowsiness explaining 36% of the variance; infant diarrhea explained 30% of the variance. Given that infant drowsiness was significantly associated with maternal dietary quality, it was important to explore whether other variables covaried with maternal food intake from animal sources, a diet quality marker. Several factors which covaried with this predictor, i.e., infant diarrheal illnesses, number of siblings and maternal age were also significantly related to infant behavior and caregiver/infant interaction. To study the combined effects of a collection of variables on infant state and behavior (Table 5), SAS PROCEDURE RSQUARE was used. This procedure indicated that a combination of maternal energy intake from animal sources and infant diarrheal illness (% time sick) explained 49% of the variance in infant drowsiness and that a combination of total energy, % energy from animal sources and infant diarrhea explained 56% of the variance (Table 6). These were the best predictor models examined of infant drowsiness.

TABLE 4
Relation of certain infant and infant/caregiver interaction variables to infant drowsiness

| Variables | Infant drowsiness, % time | | | |
|---|---|---|---|---|
| | 0 | >0-10 | >10-24 | p* |
| **Infant** | | | | |
| Morbidity, 0-6 mo | (n=12) | (n=10) | (n=7) | |
| Diarrhea, % time sick | 4.75± 6.46[a] | 5.19± 3.49[a] | 11.78± 7.98[b] | |
| Behavior, 3-6 mo | (n=19) | (n=16) | (n=12) | |
| No. of distress episodes | 0.50± 0.53[a] | 1.01± 0.78[b] | 1.00± 0.76[b] | |
| People and object involvement, % time | 5.9 ± 7.7 | 3.0 ± 6.3 | 1.9 ± 3.3 | 0.06 |
| **Infant/caregiver interaction, 3-6 mo** | | | | |
| No. of vocalizations to infant | 7.75± 3.42[a] | 5.57± 1.76[b] | 5.82± 2.44[b] | |
| Non-effective response to infant's distress, % time | (n=13) | (n=14) | (n=11) | |
| | 0.46± 0.24 | 0.50± 0.28 | 0.60± 0.18 | 0.10 |

[ab]Three group comparison by least squared difference; means with different superscripts are significantly different ($p<0.05$).
*Two group comparison: 0 and >10% time drowsy (t-test).

TABLE 5
Independent variables tested for their relation to caregiver/infant interaction and to infant state and behavior

**Mother:**
- Age
- Parity
- Child spacing
- Mean daily food intake, 0-6 months postpartum
  - Kcal - total, animal source, plant source
  - Protein - total, animal source, plant source
- Weight, 6 months postpartum
- Hematological measurements (hemoglobin, hematocrit, ferritin), 6 months postpartum

**Infant:**
- Birth weight and weights at 3 and 6 months
- Gender
- % days sick with diarrhea, respiratory tract infection or all illnesses during 0-3, 3-6 and 0-6 months

**Household:**
- Socioeconomic status
- Sanitation index
- Size and composition

TABLE 6
Multiple regression models for predicting infant drowsiness from maternal dietary variables and infant morbidity

| Independent variables | Regression Coefficient ±SE | p | $R^2$ |
|---|---|---|---|
| | **Dependent variable: Infant drowsiness** | | |
| **Final predictor models (n=25)** | | | |
| Energy intake, animal source, kcal/d | -0.025 ± 0.008 | 0.008 | 0.49* |
| Infant diarrhea, % time sick | 0.366 ± 0.151 | 0.02 | |
| Intercept | 11.5 ± 3.7 | | |
| Total energy intake, kcal/d | -0.007 ± 0.002 | 0.01 | 0.56* |
| Energy intake, % from animal sources | -0.374 ± 0.206 | 0.08 | |
| Infant diarrhea, % time sick | 0.364 ± 0.145 | 0.02 | |
| Intercept | 26.5 ± 7.0 | | |

*$R^2$ when each variable was analyzed separately relative to infant drowsiness: 0.36 for kcal/d from animal sources ($p<0.002$); 0.30 for infant diarrhea ($p<0.005$); 0.27 for total energy intake ($p<0.008$) and 0.22 for % energy from animal sources ($p<0.02$).

## Implications of Findings

The Nutrition CRSP findings showed that essentially all infants in Kalama were breastfed during the first year and many continued to be breastfed until two years of age. Food supplements commonly introduced during the first 6 months of age were sugar water, rice water and sugary concoctions, all of which are poor sources of nutrients. Other supplementary foods such as milk and cheese were given in very small amounts and to only a small number of the infants studied. Thus breast milk was the infant's main source of nutrients during the first 6 months of age, the period of this study. Presumably maternal diet, through its effects on breast milk composition, was related to certain infant outcomes.

Infants of mothers whose diets were assessed as low in both quantity and quality were sick more frequently with diarrhea, were drowsy more often and had a higher number of distress episodes compared to infants whose mothers had higher intakes of total energy and of animal source foods, a dietary quality marker in this study. Drowsy infants received less vocalization and tended to receive more non-effective responses to their distress from their caregivers. Thus the at-risk infants who needed extra attention and better child care actually received less stimulation from their caregivers.

Lower intake of animal source foods by the caregiver was also associated with lower iron intake and a poorer sanitation index of the household, both of which were related inversely to the frequency and duration of diarrheal illnesses of infants. Nutritional status of the mother is possibly associated with her capability in handling household tasks as well as in providing the child care and extra attention required by an at-risk infant. Data which may support or refute these theories are included in the Nutrition CRSP data base but have not as yet been analyzed.

## Summary and Conclusions

The findings of this study indicated that maternal diets low in quantity and quality during lactation were associated with increased infant drowsiness and morbidity, and inappropriate caregiver/infant interactions. This combination of factors could have serious long term consequences on the developmental outcomes of the infants. In this study, animal source foods were used as a dietary quality marker. While the conditions of low quantity and poor quality maternal diets and repeated illnesses of infants are potentially remediable, without such remediation, infants are at risk of impaired development. Before dietary remediation is possible, however, a detailed analysis is needed of the dietary constituents which underlie these observations. An important next step in the analysis is to identify the characteristic food group profiles of diets which appear to support desirable outcomes. This underlying information is essential to effective nutrition education or intervention programs, designed to remedy the maternal dietary factors associated with infants at-risk of impaired developmental outcomes.

## III. RELATION OF FOOD INTAKE TO MEASURES OF CAREGIVER-CHILD INTERACTION AND COGNITIVE DEVELOPMENT OF TODDLERS IN EGYPT

**Purdue University**

A relation between toddler food intake and measures of caregiver child interaction was noted in both Egypt and Kenya. Further analyses of the two country data sets indicated that the factor structure of caregiver behaviors toward toddlers is highly similar in both Kenya and Egypt; however, there is a difference in the stability of caregiver behaviors across time between Egypt and Kenya. This complete data set is due to be published as a chapter in an edited volume: Cultural Approaches to Parenting edited by Marc Bornstein.

Maternal nutritional status was also related to measures of caregiver child interaction. One critical question is whether differences in caregiver child interaction are driven by maternal nutritional status, child nutritional status or an interaction between mother and child nutritional status. Parallel analysis from both Kenya and Egypt indicated that variability in caregiver child interaction was primarily accounted for by toddler food intake rather than maternal food intake per se. These results will be submitted for publication to the International Journal of Behavioral Development.

Detailed multivariate analyses have been used to examine the relation between toddler food intake and measures of toddler cognitive development and behavior. The results of this analysis indicated the following: 1. Toddler intake of animal source food, a dietary quality marker, appeared to be related to a number of specific measures of cognitive development, particularly during the 18 to 23 month age period. Cognitive measures that appeared to be especially sensitive to the toddler's dietary quality were symbolic play, Bayley Mental Scores and the child's reactivity during testing. There appeared to be little systematic relation between the dietary quality of toddlers and measures of ongoing toddler behavior. 2. In contrast, measures of caregiver child interaction appeared to be systematically related to measures of ongoing toddler behavior. Critical caregiver behaviors appeared to include the number of spontaneous vocalizations to the child, the amount of nonverbal responsiveness to the child's vocalization and whether the caregiver was within reach of the child. Measures of toddler's ongoing behavior that appeared to be especially related to measures of caregiver behavior included simultaneous involvement with persons plus objects, the degree to which the child was in an active alert state and the number of spontaneous child vocalizations. In contrast to dietary quality markers, measures of caregiver behaviors did not appear to be related to measures of toddler test performance. 3. Relations between morbidity and either toddler test performance or ongoing toddler behavior appeared to be scattered and inconsistent. Similarly, measures of hematology also appeared not to bear strong relations to measures of toddler cognitive performance or ongoing behavior. These results are now being prepared for publication.

## IV. ESTIMATION OF DIETARY QUALITY FOR TODDLERS IN EGYPT

**University of Arizona**

This report summarizes analyses to date directed toward the goal of detailed description of the quality of diets among toddlers in the Egypt project, Nutrition CRSP with a view to developing variables which may be useful in methods predicting cognitive outcomes. The results presented are as yet incomplete and preliminary, and subject to further refinement before final use in models predicting functional outcomes. We have chosen to describe dietary intake in terms of (a) nutrient intake and (b) consumption of specific food items. The former set of variables will be of obvious use in testing biologically-based hypotheses. The latter set of descriptive analyses, based on food items, may with further refinement be the basis for understanding cultural definitions of dietary quality, which may be an important indication of quality of child care in culturally relevant terms. Following each section, we discuss briefly the significance of these findings for relating dietary quality to cognitive function in further analyses.

### A. Nutrient Intakes

Our first task was to describe the intakes of energy and key nutrients in relation to weaning status, age, calendar month (season), gender, and illness. Theoretically, age and calendar month were controlled in the study design since all children were the same age (18 to 30 months) and were followed for a full calendar year. However, study entry and calendar month were not randomly distributed with respect to one another, and variability in weaning age and inclusion of both boys and girls in the study provide the opportunity for a number of interactions. In addition, some of the functional variables of interest for ultimate analysis are highly age-dependent and some (i.e., morbidity) are season-dependent as well. Thus analyses which focus on less than a full calendar year of data must take any age and seasonal variation in food intake into account.

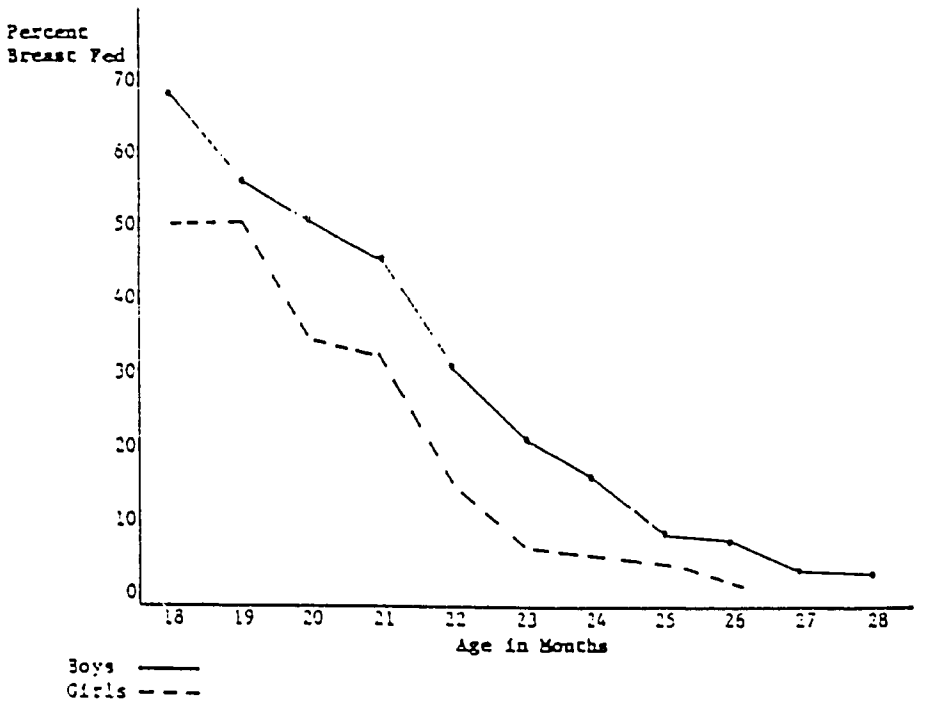
The data presented in this report represent intake of nutrients from food other than breastmilk. Intakes of energy and of micronutrients are based on the food composition database compiled during the CRSP project. We expect to re-run our analyses using the updated and expanded food composition database being prepared by UC Berkeley under the current Cooperative Agreement.

We have chosen to present data on energy (kcal/kg/day); protein from animal and from plant sources (kg/kg/day); fat from animal and from plant sources (g/kg/day); iron from animal and from plant sources (mg/day); preformed vitamin A (micrograms/day) and beta-carotene (i.u./day). Iron and vitamin A were chosen because they are likely to be at least mildly deficient in this population. Separate variables to reflect the contribution of animal sources will reflect both nutritional and cultural quality of the diet. When the revised food composition database is available to us, we will also incorporate zinc from animal and plant sources, phytate, and fiber intake as food quality variables. For nutrient intakes expressed in relation to body weight, the weight on that date was imputed from the regression line of all body weights for that child on age.

Weaning status. Sixty percent of toddlers were still partially breastfed at study entry (age 18 months), with slightly more boys than girls in this category. Dates of last breastmilk intake for these children were distributed fairly evenly over the period from 18 to 23 months, after which only a few children were still breastfed. Figure 1 (from the CRSP final report, Egypt Project, p. 176) shows the percent of target toddlers who were still receiving some breastmilk at each age, by gender. By age 28 months all of the study toddlers were completely weaned, and after 22 months energy intakes/kg body weight from non-breastmilk sources were not different for those children who had been completely weaned vs those who were still reported to be breastfed.

FIGURE 1

Percent of target toddlers who had a food intake measurement in a given month who were partially breast-fed by age

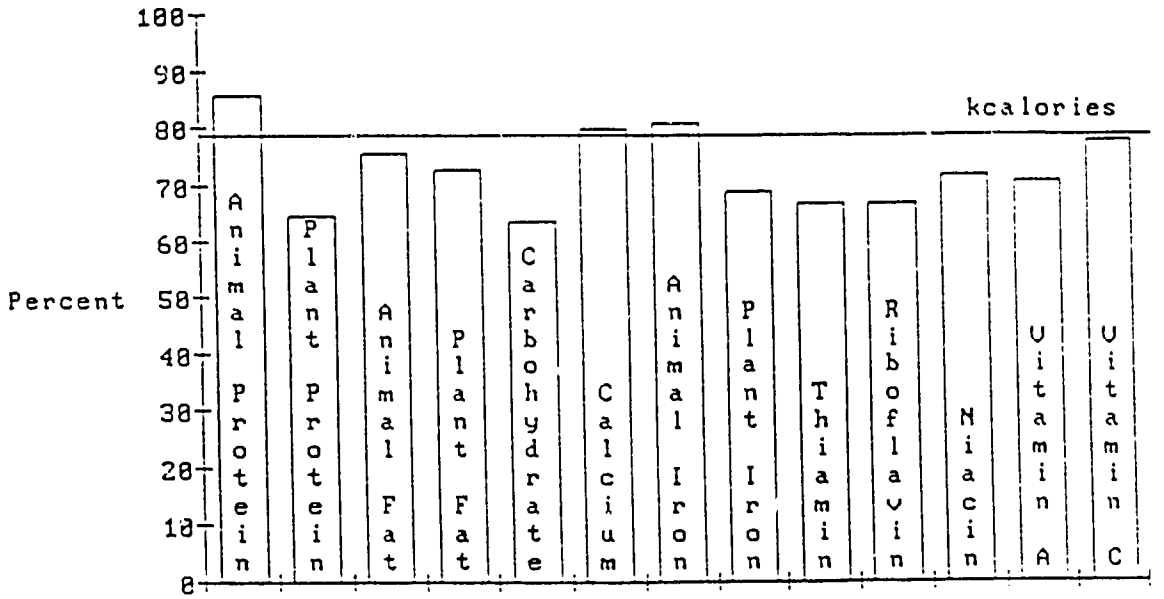



For all days of food intake data (N=2256), energy intake from non-breast milk sources on weaned days was 21 percent higher than on partially breast-fed days. Thus while breastmilk represents a real supplement during the study period for those children who continued to receive it, all target toddlers derived the greatest part of their food intake from sources other than breastmilk throughout the study.

Figure 2 shows mean intakes of various nutrients from non-breast milk sources for partially-breastfed days as a percent of mean intake on weaned days. Nutrient density of the non-breastmilk diet was lower for children who were partially breastfed for most nutrients, but not for animal protein, iron from animal sources, and calcium which met or exceeded the nutrient density of the post-weaning diet. Thus it appears that the diets given children while partially breastfed was relatively somewhat higher in animal products than that given children after full weaning.

FIGURE 2

Mean Nutrient Intake on Breast-fed Days
as a Percent of Weaned Days




Season. The CRSP fieldwork spanned two calendar years, with each individual target child followed for one year. The religious calendar may influence food consumption and does not coincide exactly with the Roman calendar; further, the dates of holidays and significant events on the Islamic calendar are slightly earlier in the Roman year during the second year of fieldwork than the first. Thus we elected to treat each of the 24 months of data collection as a separate month in analysis. Again using the food intake day as the unit of analysis (N=2256), analysis of covariance with age in months and gender as covariates showed no effect of calendar month on energy intake expressed per kg body weight. This is consistent with earlier analyses presented in the project final report which controlled for breastfeeding status as well.

Gender. All analyses to date show a significant effect of gender on energy intake in this database, with girls consuming more food energy/kg body weight than boys. In the covariance analysis, the effect was highly significant ($p<.0001$). There may be some confounding with weaning age over the period of the year, since girls were on averaged weaned somewhat earlier than boys and thus would have a greater risk of more study days in which non-breastmilk represented total intake. However, Table 1 (from the CRSP final report) shows that this effect is present consistently for those children who are fully weaned at each age.

Table 1
Median toddler food intake (non-breast milk), kcal/kg/day*

| Age in Months | Males | | Females | |
|---|---|---|---|---|
| | Weaned | Not Yet Weaned | Weaned | Not Yet Weaned |
| 18 | 86 (16) | 68 (36) | 98 (23) | 78 (21) |
| 19 | 93 (21) | 72 (27) | 97 (21) | 78 (21) |
| 20 | 102 (22) | 82 (22) | 108 (25) | 109 (14) |
| 21 | 94 (26) | 71 (17) | 116 (28) | 84 (12) |
| 22 | 98 (34) | 80 (15) | 109 (35) | 82 (6) |
| 23 | 90 (38) | 101 (9) | 107 (36) | 94 (3) |
| 24 | 107 (40) | 133 (8) | 104 (35) | 65 (1) |
| 25 | 86 (48) | 104 (3) | 102 (34) | 83 (2) |
| 26 | 89 (45) | 99 (3) | 115 (37) | |
| 27 | 90 (48) | 180 (1) | 98 (38) | |
| 28 | 89 (43) | | 95 (40) | |
| 29 | 89 (42) | | 94 (39) | |

*Estimated weight based on regression of weight on age for each subject.

Age. Figures 3 through 11 show adjusted mean intake of energy and the index nutrients by age in months, adjusted by covariance analysis for calendar month and gender. In further analysis, we will adjust for the effect of weaned/partially breastfed status on these relationships. For the present, it important to remember that the apparent gradual increase in energy intake between 18 and 24 months represents an increase in the number of children fully weaned during this age span. The average energy intake appears adequate based on international recommendations (105 kcal/kg/day for children 1-2 years and 100 kcal/kg/day between 2 and 3 years).

FIGURE 3

Mean non-breast milk Energy (Kcal/kg/d) intake (adjusted for season and gender) by age in months.

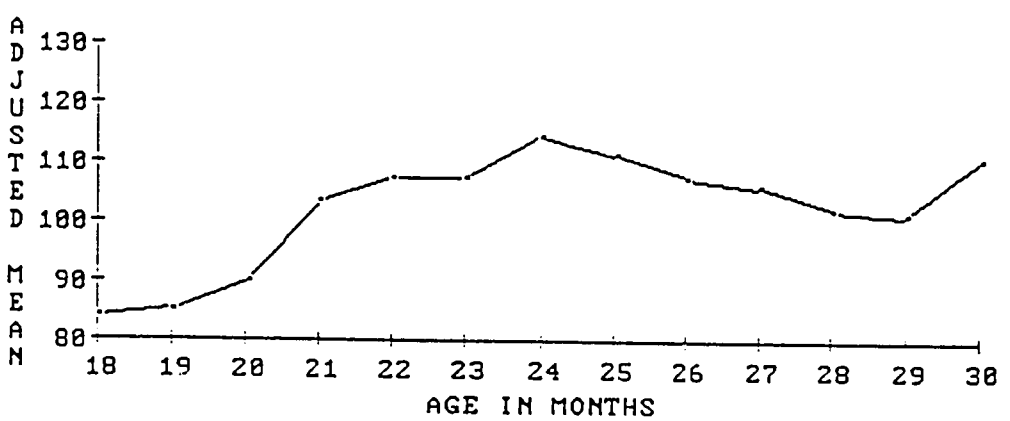


FIGURE 4

Mean Protein (Gm/kg/d) intake from animal sources (adjusted for season and gender) by age in months.

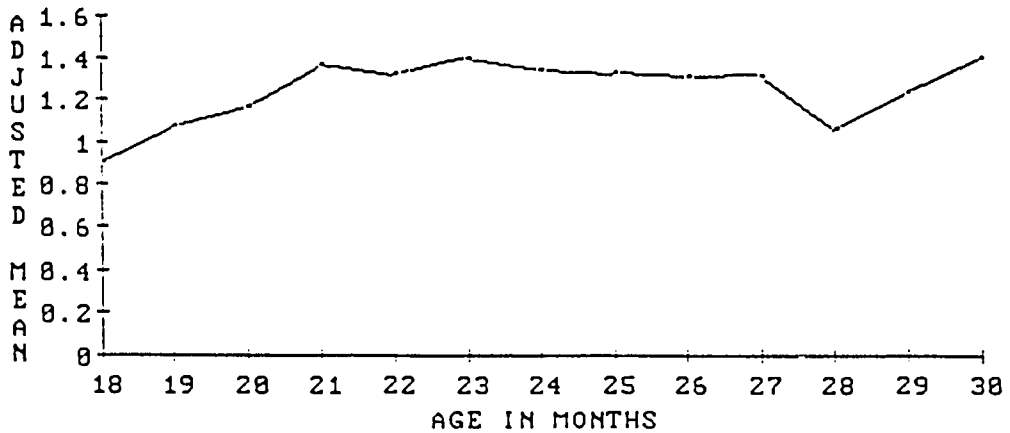



FIGURE 5

Mean Protein (Gm/kg/d) intake from plant sources (adjusted for season and gender) by age in months.

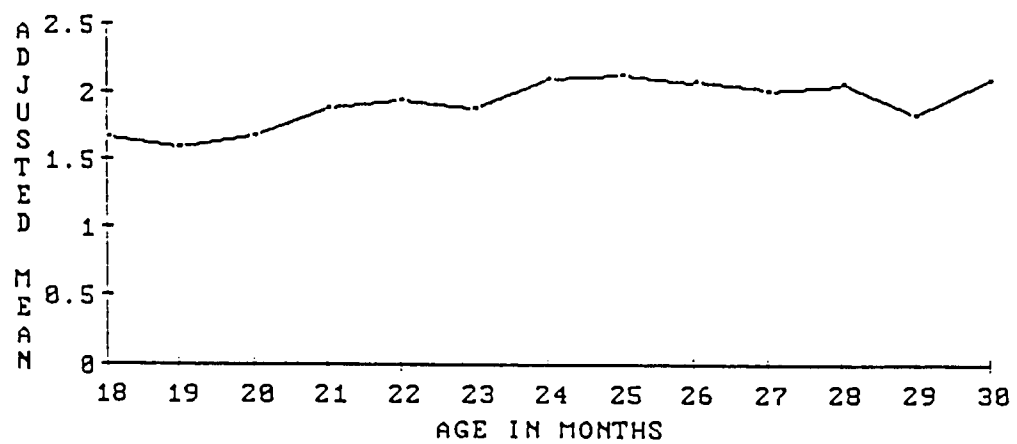



FIGURE 6

Mean Fat (Gm/kg/d) intake from animal sources (adjusted for season and gender) by age in months.

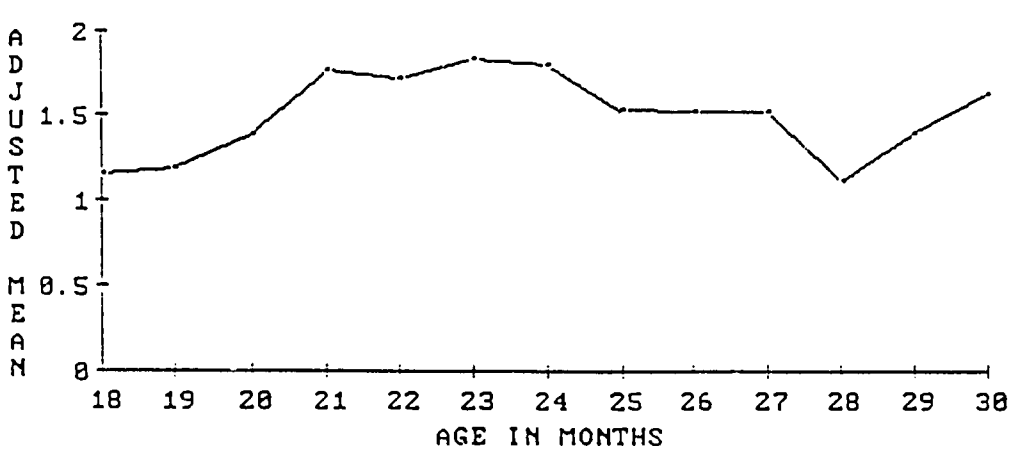


FIGURE 7

Mean Fat (Gm/kg/d) intake from plant sources (adjusted for season and gender) by age in months.

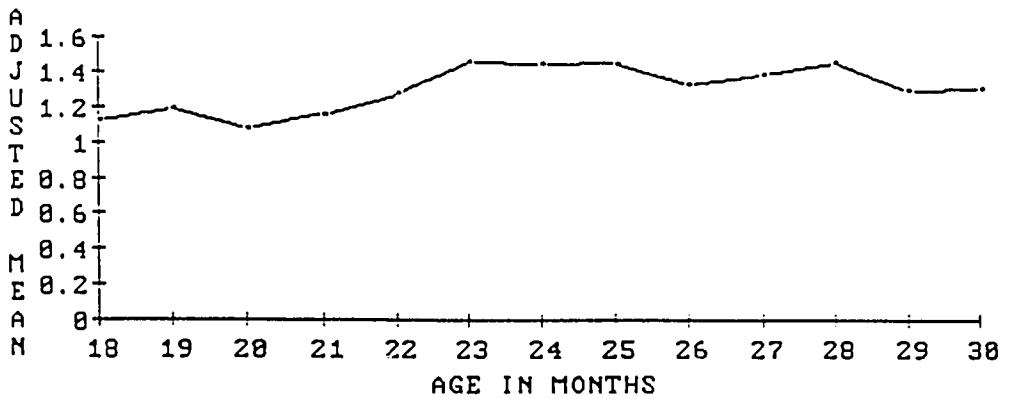



FIGURE 8

Mean Iron (mg) intake from animal sources (adjusted for season and gender) by age in months.

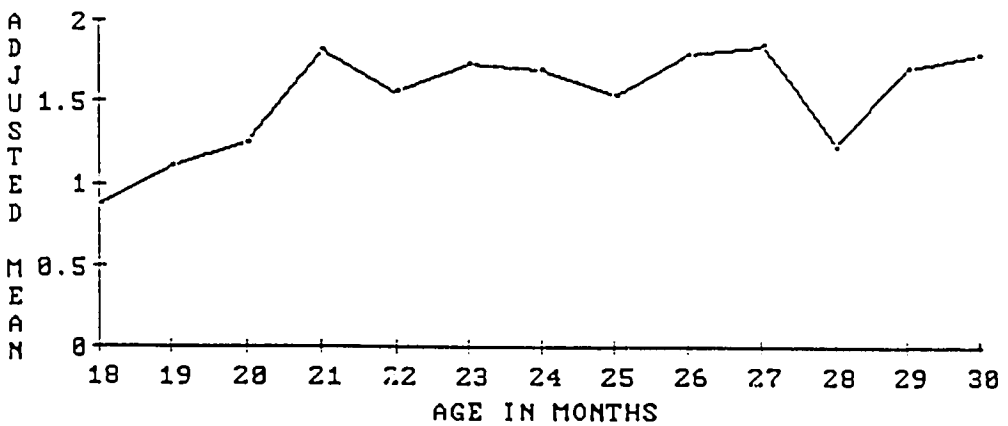



FIGURE 9

Mean Iron (mg) intake from plant sources (adjusted for season and gender) by age in months.

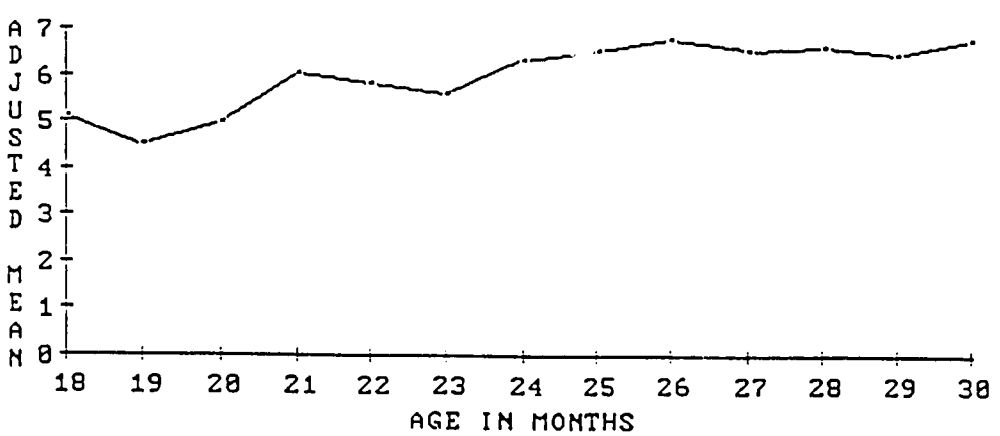


FIGURE 10

Mean Vitamin A (ug) intake (adjusted for season and gender) by age in months.

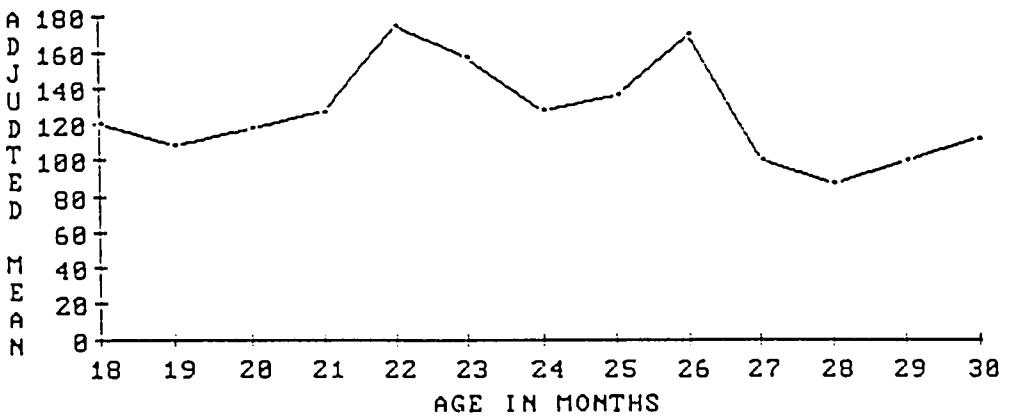
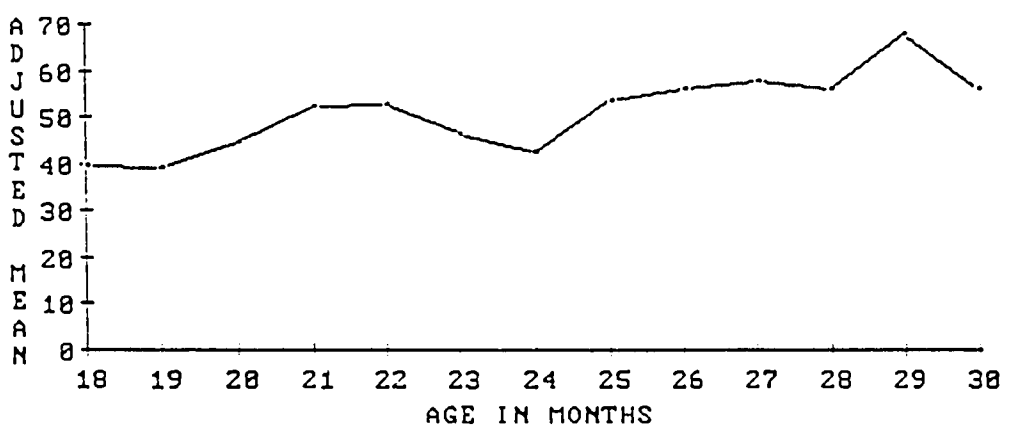



FIGURE 11

Mean Beta-carotene (ug) intake (adjusted for season and gender) by age in months.




Illness and Nutrient Intake. Food intake observations were scheduled for two days per month independent of illness; about ten percent of food intake observations coincided with illness. Earlier analyses, presented in the project's final report, have shown that there was no difference in likelihood of a food intake measure occurring on ill vs well days.

Table 2 shows energy intake (mean ± standard deviation) on days in which the child was well versus days with any illness, diarrhea and respiratory illness. Overall, energy intake was slightly (less than 5%) lower on ill days than well days; this difference was not statistically significant. Examination of specific illness categories shows that most of the food intake deficit on illness is accounted for by a significant decrease (11.6%) in energy intake during mild diarrheal episodes. Severe diarrheal episodes were associated with a slight increase in energy intake over well days (3.8%). Respiratory illnesses as a

whole had little influence on food intake, but mild respiratory episodes were associated with higher energy intakes than on well days (+11.6%). It is tempting to speculate that this pattern represents behavior which includes purposeful feeding of children when they are ill or during recovery; if so, it is likely that mild diarrhea may be regarded as not serious enough to invoke such home treatment and that the slight decrease in energy intake seen with mild diarrhea is appetite-driven.

Table 2
Energy intake on well days, days with diarrheal illness, and day with respiratory illness

| | Kcal/kg/day (mean +/- sd) | % change |
|---|---|---|
| Well days (N=2157) | 103 ± 51 | |
| Days with any illness (N=205) | 98 ± 52 | -4.8% |
| Days with diarrhea (N=76) | 102 ± 59 | No change |
| Mild (N=50) | 91 ± 55 | -11.6% |
| Severe (N=26) | 107 ± 61 | +3.8% |
| Days with respiratory illness (N=60) | 106 ± 51 | +2.8% |
| Mild (N=41) | 115 ± 51 | +11.6% |
| Severe (N=19) | 102 ± 52 | No change |

Index nutrients were examined in the same fashion; the only significant difference in intake between ill and well days was a decrease in fat from plant sources (oils) with illness and specifically with diarrheal illness.
Figures 12-19 show gender- and calendar month-adjusted means by age for intake of energy and each of the key nutrients for well and ill days (all illnesses). Further analysis will smooth these curves, which in their raw form are somewhat unstable for ill days due to the smaller sample size in this condition. It is evident even from the unsmoothed curves that any decreases in intake with illness occur in children 24-30 months of age; further analysis will explore the effect of illness separately for children less and more than 24 months of age.

FIGURE 12

Mean non-breast milk Energy (Kcal/kg/d) intake (adjusted for season and gender) by age in months.

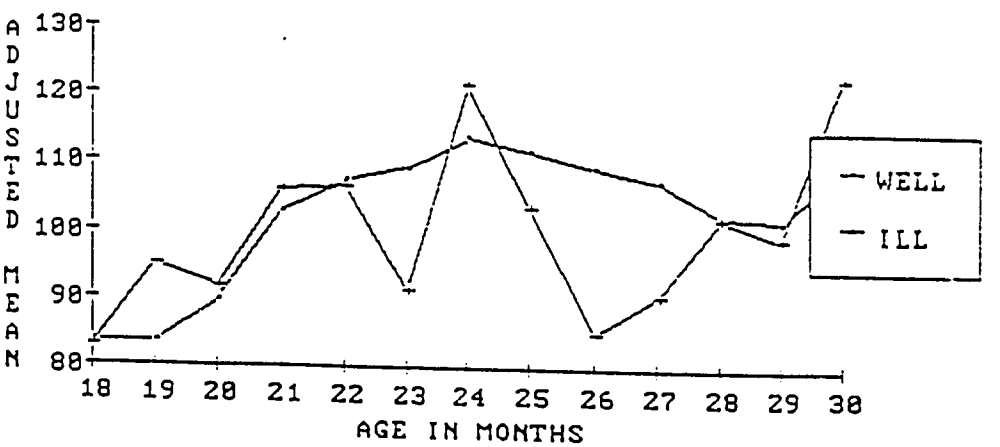


FIGURE 13

Mean Protein (Gm/kg/d) intake from animal sources (adjusted for season and gender) by age in months.

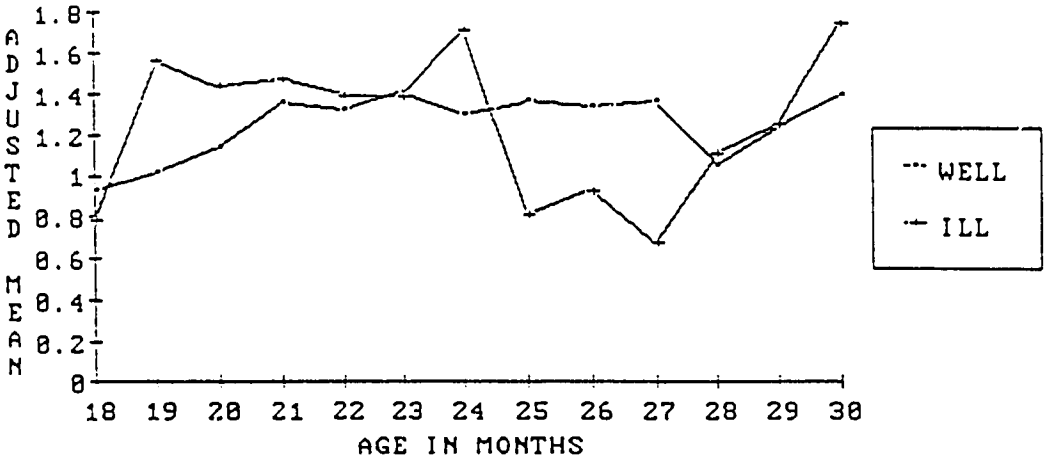



FIGURE 14

Mean Protein (Gm/kg/d) intake from plant sources (adjusted for season and gender) by age in months.

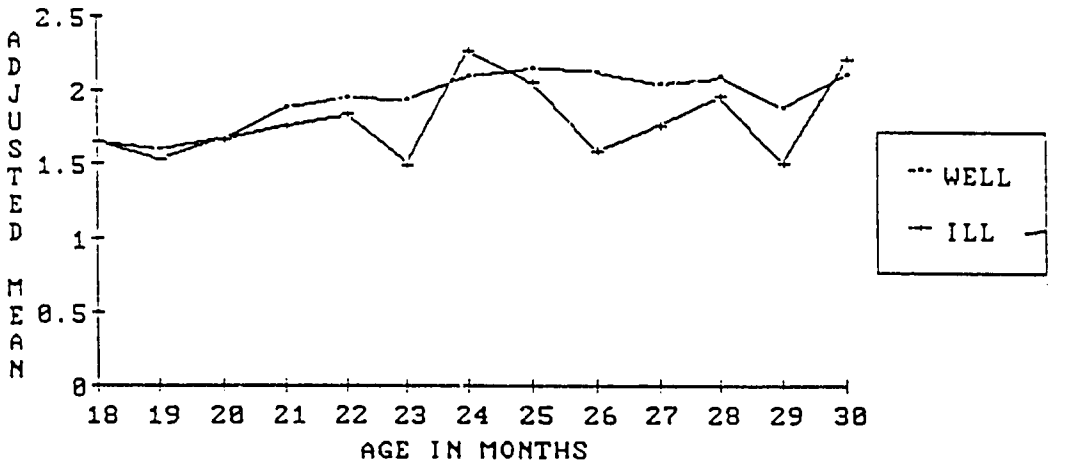



FIGURE 15

Mean Fat (Gm/kg/d) intake from animal sources (adjusted for season and gender) by age in months.

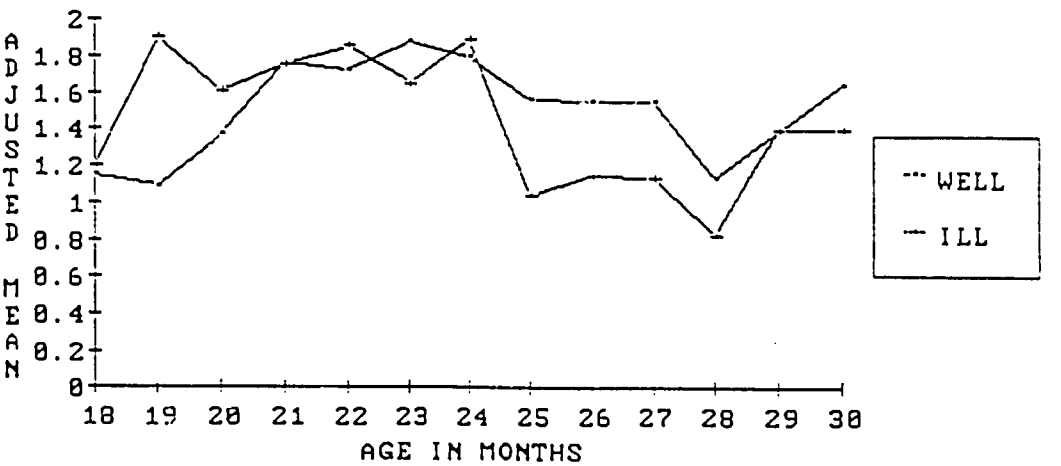


FIGURE 16

Mean Fat (Gm/kg/d) intake from plant sources (adjusted for season and gender) by age in months.

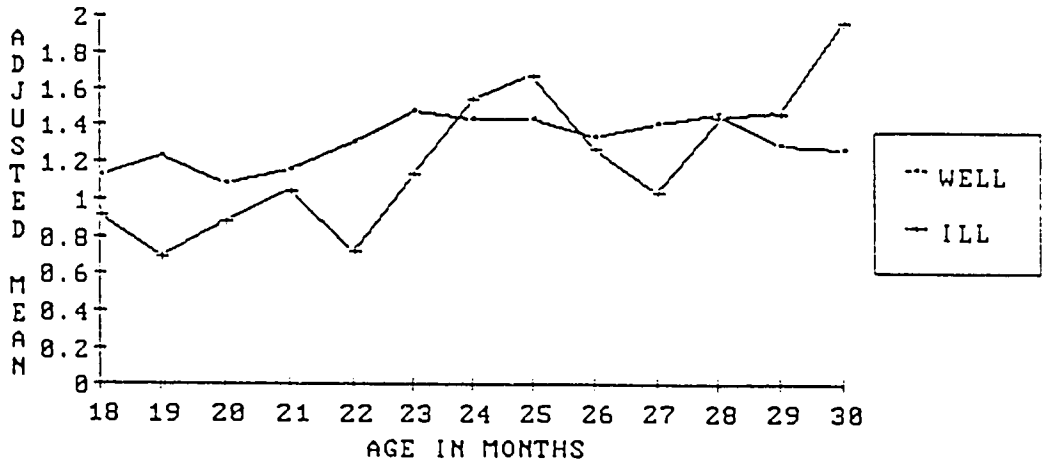



FIGURE 17

Mean Iron (mg) intake from animal sources (adjusted for season and gender) by age in months.

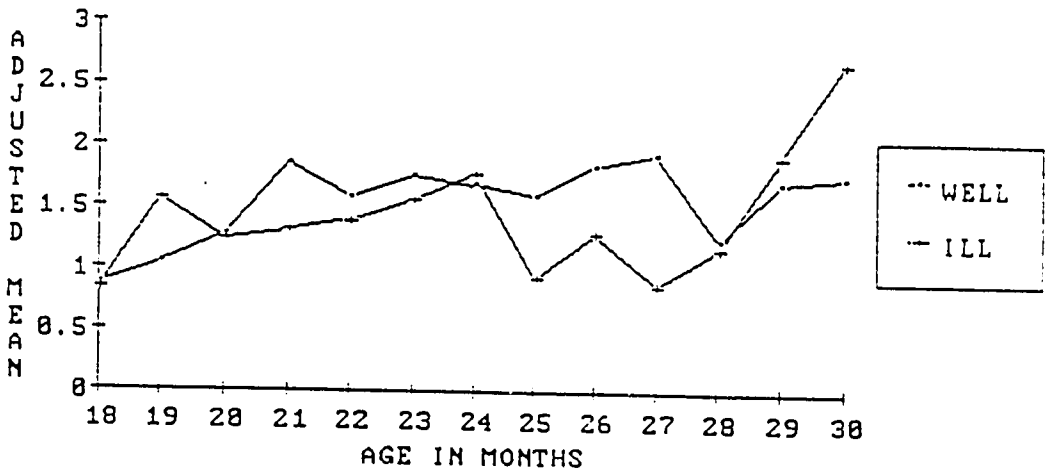



FIGURE 18

Mean Iron (mg) intake from plant sources (adjusted for season and gender) by age in months.

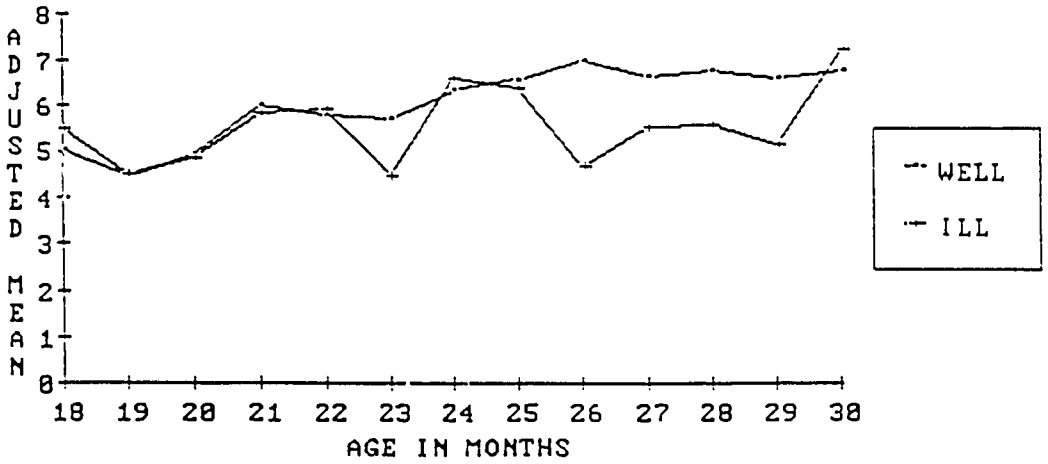


FIGURE 19

Mean Vitamin A (ug) intake (adjusted for season and gender) by age in months.

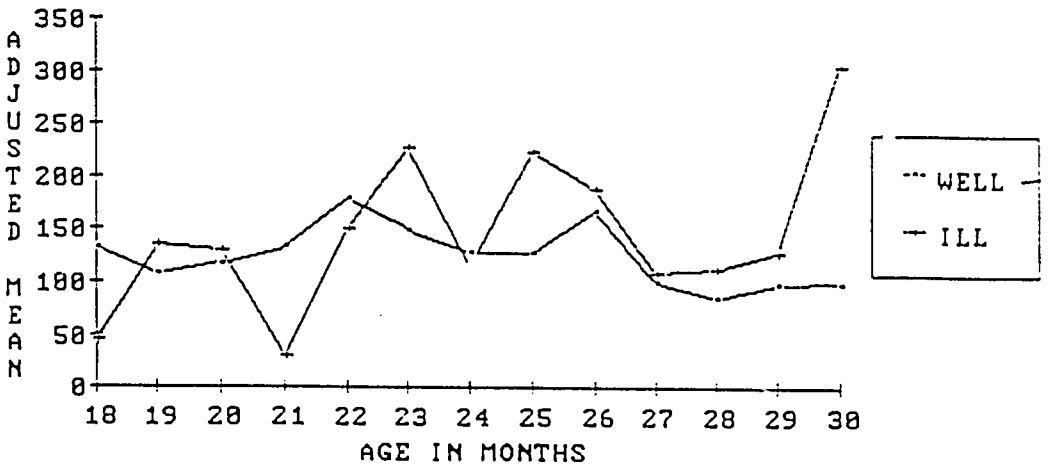
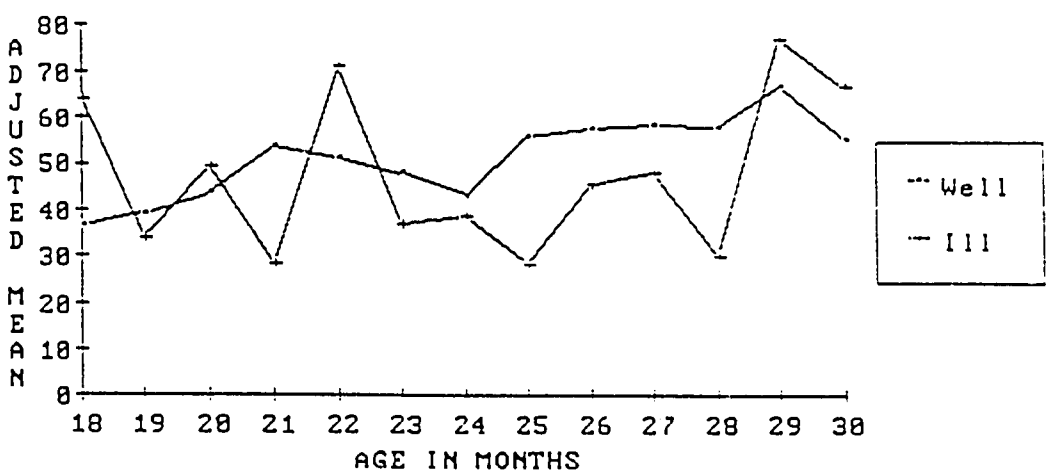



FIGURE 20

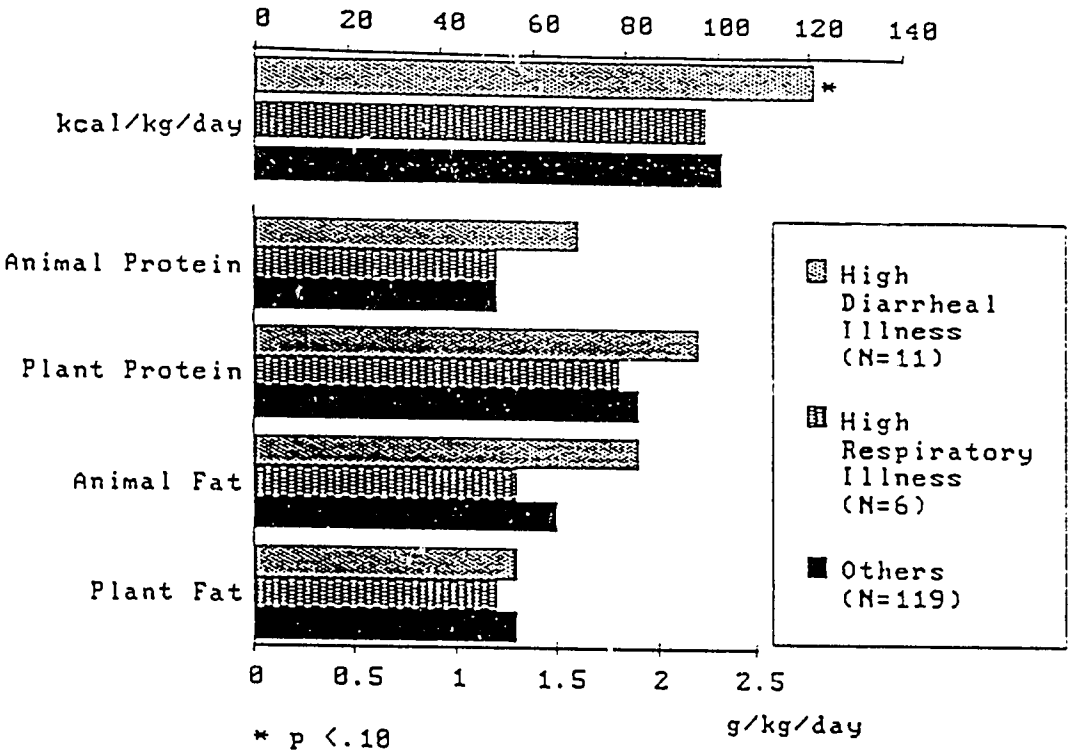
Mean Beta-carotene (ug) intake (adjusted for season and gender) by age in months.




To examine whether high morbidity burden over the year was associated with differences in food intake, we compared the yearly average intakes of those children who had 10 or more weeks with respiratory infection (N=6), those who had 10 or more weeks with diarrheal illness (N=11) and the remainder of the children (N=119). Figure 21 shows the results for kcalories, protein and fat from animal and plant sources. Children with the highest burdens of diarrheal illness had somewhat greater energy intake over the year than others ($p > .05 < .10$); the trends toward higher intakes of animal and plant protein and of animal fat are in the same direction but not statistically significant.

Figure 21

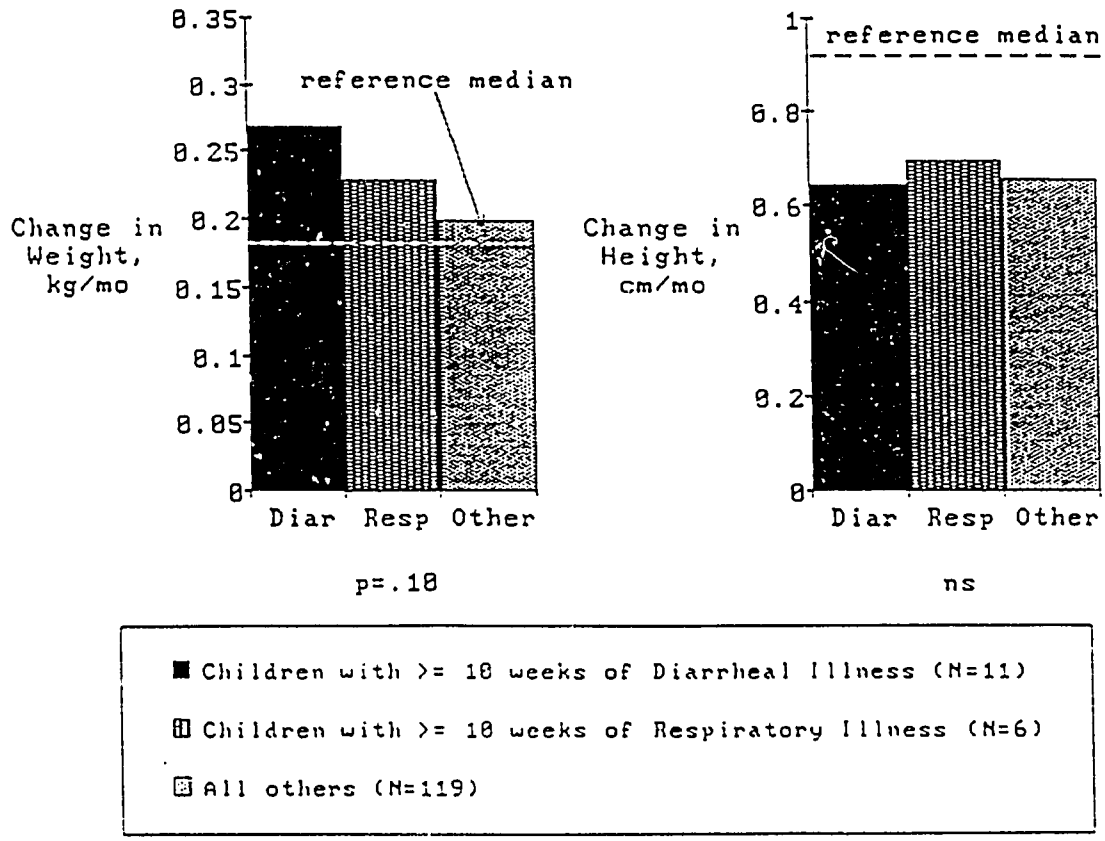
Mean Nutrient Intakes Over One Year of Children with >= 10 Weeks with Diarrhea or Respiratory Illness, Compared to Others




In separate analyses predicting change in weight over the year, morbidity variables have proved consistently significant in a counter-intuitive direction (i.e., greater morbidity predicting greater weight gain). This relationship is depicted in Figure 22, which again compares those children with the highest diarrheal and respiratory illness burdens with the rest. The group as a whole was gaining weight at a rate slightly above the reference median, with those children with the greatest amount of illness (particularly diarrhea) gaining the most rapidly. This effect is not seen in relation to gain in height. The finding that high morbidity burden is associated with increased food intake over the year reinforces this finding, and argues for increased intake either during illness or in intervening well periods. In later analyses, we plan to attempt to examine intakes during the early part of post-illness periods.

Figure 22

Mean Velocity of Change in Weight and Height, 18-30 Months for Children with >= 10 Weeks of Diarrhea or Respiratory Illness, and Others




**Discussion: The fact that illness is not closely associated with decreased food intake in this population, and in some children may even be associated with increased intake during or after illness suggests that it may be possible to understand the independent relationships of morbidity and nutrient intake to cognitive function.**

B. Consumption of Specific Food Items

We will eventually analyze food items on a "usual intake" basis for individual children as a reflection of culturally-defined dietary quality. The present analysis is limited to consideration of the relationships between illness and consumption of specific food items, and is based on the child-observation-day as the unit of analysis (2558 well days and 225 days with illness of any type). In order to do this, we grouped foods into 40 categories. Not all categories are mutually exclusive; category definitions can be found in the appendix.

Table 3 shows the percentage of food observation days in which foods from each category were consumed on well days and on days with illness. Food intake on days with illness was significantly more likely to include soft drinks, puddings, eggs, fish, breast milk, other milks, sweets and sweet products (excluding sugar). There was a decreased likelihood of consumption of some vegetables.

**Table 3**
**Percentage of well and sick days on which specific foods were consumed**

| FOOD GROUPS | WELL DAYS N=2558 | ILL DAYS N=225 | p |
|---|---|---|---|
| 1. Beverages, noncarbonated | 83.7 | 80.0 | ns |
| 2. Beverages, soft drinks | 2.3 | 4.4 | <.05 |
| 3. ORS | 0.0 | 0.0 | -- |
| 4. Cereals, rice | 47.0 | 44.4 | ns |
| 5. Cereals, whole grains | 1.8 | 0.4 | ns |
| 6. Cereals, macaroni | 18.1 | 19.1 | ns |
| 7. Cereals, rural bread | 86.6 | 83.1 | ns |
| 8. Cereals, bread | 41.9 | 43.1 | ns |
| 9. Starch-based pudding | 0.3 | 1.3 | <.01 |
| 10. Pastry with ghee | 0.5 | 0.0 | -- |
| 11. Eggs and egg products | 19.5 | 25.8 | <.01 |
| 12. Oil/Fat animal sources | 52.0 | 51.1 | ns |
| 13. Oil/fat plant sources | 70.9 | 66.7 | ns |
| 14. Fish, all varieties | 3.3 | 5.8 | <.05 |
| 15. Fruits, regular | 17.2 | 16.9 | ns |
| 16. Fruits, citrus | 16.1 | 16.9 | ns |
| 17. Fruit juices | 3.8 | 5.8 | ns |
| 18. Legumes, broad bean | 19.4 | 15.6 | ns |
| 19. Legumes, others | 7.2 | 6.7 | ns |
| 20. Legume products | 29.7 | 28.4 | ns |
| 21. Meat | 20.6 | 17.3 | ns |
| 22. Meat products | 43.0 | 38.2 | ns |
| 23. Human milk | 15.0 | 20.4 | <.01 |
| 24. Milk, other | 16.3 | 21.8 | <.01 |
| 25. Milk products | 69.5 | 72.9 | ns |
| 26. Nuts | 2.0 | 1.8 | ns |
| 27. Seasoning, salt | 76.5 | 72.9 | ns |
| 28. Seasoning, condiments | 33.0 | 32.0 | ns |
| 29. Sweets, Sugar | 89.2 | 88.4 | ns |
| 30. All sweets & sweets products | 41.5 | 49.3 | <.01 |
| 31. Tubers, all | 32.7 | 33.8 | ns |
| 32. Potatoes | 29.0 | 30.7 | ns |
| 33. Vegetables, eggplants | 9.2 | 7.1 | ns |
| 34. Vegetables, raw/salad | 27.5 | 26.7 | ns |
| 35. Vegetables, tomato | 66.1 | 66.7 | ns |
| 36. Vegetables, onions & garlic | 64.8 | 60.9 | ns |
| 37. Vegetables, orange/ yellow | 3.2 | 4.0 | ns |
| 38. Vegetables, olives | 00.0 | 00.0 | -- |
| 39. Vegetables, all other types | 39.3 | 29.3 | <.001 |
| 40. All vegetables except salad & olives | 81.2 | 76.9 | ns |

Table 4 shows the percentage of observation days in which foods from each category were consumed for well days (N=2558), days with diarrheal illness (N=80) and days with respiratory illness (N=71). On days with diarrhea, there are highly significant decreases in likelihood of consuming the rural staple bread (p=.007), oil (p<.01), seasonings (p<.05), onions & garlic (p=.01), and cooked vegetables (p<.01); children with diarrhea were more likely to consume soft drinks (p<.05), puddings (p=.0001), and sweets & sweet products (p<.05) than on well days. (The zero consumption of oral rehydration solution, item #3, reflects the fact that the CRSP fieldwork took place before the massive public education campaign on use of ORS for diarrhea began). On days with respiratory illness, there was increased likelihood of consuming fruit juices (p<.0001), yellow and orange vegetables (p<.05), and milk other than breastmilk (p<.05); there was a significant decrease in likelihood of consumption of fool (bread, beans); the legume staple.

**Table 4**
**Percentage of well days and days with diarrhea and respiratory illnesses on which specific foods were consumed**

| FOOD GROUPS | WELL N=2558 | DIARRHEA N=80 | RESPIRATORY N=71 |
|---|---|---|---|
| 1. Beverages, noncarbonated | 83.7 | 81.3 | 80.3 |
| 2. Beverages, soft drinks | 2.3 | 6.3* | 1.4 |
| 3. ORS | 0.0 | 0.0 | -- |
| 4. Cereals, rice | 47.0 | 48.8 | 56.3 |
| 5. Cereals, whole grains | 1.8 | 0.4 | 0.0 |
| 6. Cereals, macaroni | 18.1 | 13.8 | 19.7 |
| 7. Cereals, rural bread | 86.6 | 76.3** | 85.9 |
| 8. Cereals, bread | 41.9 | 46.3 | 39.4 |
| 9. Starch-based pudding | 0.3 | 3.8*** | 1.4 |
| 10. Pastry with ghee | 0.5 | 0.0 | 0.0 |
| 11. Eggs and egg products | 19.5 | 28.8* | 22.5 |
| 12. Oil/Fat animal sources | 52.0 | 55.0 | 56.3 |
| 13. Oil/fat plant sources | 70.9 | 57.5** | 66.2 |
| 14. Fish, all varieties | 3.3 | 5.0 | 2.8 |
| 15. Fruits, regular | 17.2 | 18.8 | 11.3 |
| 16. Fruits, citrus | 16.1 | 21.3 | 16.9 |
| 17. Fruit juices | 3.8 | 1.3 | 14.1*** |
| 18. Legumes, broad bean | 19.4 | 17.5 | 9.9 |
| 19. Legumes, others | 7.2 | 5.0 | 8.5 |
| 20. Legume products | 29.7 | 31.3 | 21.1 |
| 21. Meat | 20.6 | 17.5 | 18.3 |
| 22. Meat products | 43.0 | 38.8 | 42.3 |
| 23. Human milk | 15.0 | 17.5 | 16.9 |
| 24. Milk, other | 16.3 | 22.5 | 25.4* |
| 25. Milk products | 69.5 | 70.0 | 70.4 |
| 26. Nuts | 2.0 | 2.5 | 1.4 |
| 27. Seasoning, salt | 76.5 | 70.0 | 76.1 |
| 28. Seasoning, condiments | 33.0 | 21.3* | 36.6 |
| 29. Sweets, Sugar | 89.2 | 92.5 | 93.0 |
| 30. Other sweets & sweet products | 41.5 | 55.0** | 43.7 |

| FOOD GROUPS | WELL N=2558 | DIARRHEA N=80 | RESPIRATORY N=71 |
|---|---|---|---|
| 31. Tubers, all | 32.7 | 28.8 | 26.8 |
| 32. Potatoes | 29.0 | 26.3 | 22.5 |
| 33. Vegetables, eggplants | 9.2 | 7.5 | 9.9 |
| 34. Vegetables, raw/salad | 27.5 | 22.5 | 28.2 |
| 35. Vegetables, tomato | 66.1 | 62.5 | 66.6 |
| 36. Vegetables, onions & garlic | 64.8 | 51.3** | 67.6 |
| 37. Vegetables, yellow/orange | 3.2 | 1.3 | 7.0* |
| 38. Vegetables, olives | 00.0 | 00.0 | -- |
| 39. Vegetables, all other type | 39.3 | 23.8** | 45.1 |
| 40. All vegetables except salad & olives | 81.2 | 70.0** | 85.9 |

* Difference from well days, $p<.05$
** Difference from well days, $p<.01$
*** Difference from well days, $p<.001$

Discussion: The data show specific food consumption changes during illness, both prescriptive and proscriptive and rather specific for type of illness. The degree to which these are utilized for a particular child over the course of a year may be a variable which reflects culture-specific home treatment of illness. This is potentially an important child-care variable in models predicting cognitive function.

## V. DIETARY QUALITY AND COGNITIVE FUNCTION IN TODDLERS AND SCHOOL AGE CHILDREN IN KENYA

**University of California, Los Angeles**

Three analyses were performed which indicate a relationship between quantity and quality of food intake and cognitive performance in both toddlers and in school age children in Kenya. These analyses appear in published papers which are included with this report (Appendices C-F). What follows is a summary of the relevant findings from these papers that mainly address diet quality and cognitive function, although detailed information on diet quality is just now becoming available from the CRSP group at UC Berkeley (Calloway and Murphy). A paper (Appendix C) on toddlers is included as it demonstrates a relationship between the qualitative aspects of the diet with symbolic play and verbalization. A second paper demonstrates that cognitive performance in these same toddlers, upon reaching school age, is related to the quantity and quality of the diet of these children when they were toddlers (Appendix D). Another paper demonstrates the relationship of current food intake and aspects of diet quality with the attention aspect of classroom behavior as well as cognitive function in school age children (Appendix E).

### Nature of the Diet in Kenyan Children

The description of the diet has been well documented in the Final Report of the Nutrition CRSP Kenya Project Report (1987). In general the diet, particularly for toddlers and less so for schoolers, is low in energy. Protein intake appears to be adequate in amount with no deficiencies or imbalances found in the amino acid patterns according to the very preliminary analyses by the CRSP research group at University of California at Berkeley (Calloway and Murphy). However, protein from animal sources comprises a very small portion of the diet and fat intake is generally low (see Table 1).

Table 1
Nutrient intake in Kenyan schoolers and toddlers by sex

| | Schoolers | | Toddlers | |
|---|---|---|---|---|
| | Males | Females | Males | Females |
| Energy (mean Kcal/d) | 1513 ± 644 | 1357 ± 592 | 841 ± 452 | 805 ± 432 |
| % FAO Recommended Energy Intake | 93 | 93 | 79 | 78 |
| Total Protein (g/d) | 45 ± 22 | 40 ± 19 | 23 ± 15 | 21 ± 14 |
| Animal Protein (g/d) | 2.7 ± 5.8 | 2.5 ± 4.6 | 3.1 ± 5.6 | 3.9 ± 6.5 |
| % protein Kcal from animal sources | 6.0 | 6.3 | 13.5 | 18.6 |
| Fat (g/d) | 22 ± 12 | 20 ± 11 | 13 ± 11 | 14 ± 11 |
| % Kcal from fat | 13 | 13 | 13.9 | 15.7 |
| Iron (mg/d) | 13.5 ± 7.0 | 12.5 ± 7.2 | 6.6 ± 4.9 | 6.0 ± 4.4 |

Considering the low dietary protein from animal sources, there is a presumption that zinc and iron intakes are low and that phytates and fiber are high because of the vegetarian nature of the diet. This is, in fact, being borne out by the recent but preliminary dietary analyses by the UC Berkeley CRSP group.

The low fat and animal protein intakes not only adversely affect the quality of the diet in that animal protein contains minerals and trace metals and fat is a concentrated source of calories, but they also appear to be markers for other characteristics of the family which affect cognitive function. For example, using Pearson's correlations there are significant correlations between these nutrients and socio-economic status, literacy, and educational level of the parents. Also, both hemoglobin and fat intake correlate highly with animal protein. Within the five different food constituents, total energy intake correlates strongly with fat, animal protein and total protein (see Table 2).

Table 2
Correlations between SES and food intake in Kenyan children

| Food intake variables | Females | Males |
|---|---|---|
| KCalories | .22 | .32* |
| Protein | .23 | .30* |
| Animal Protein | .56* | .52* |
| Fat | .49* | .52* |
| Carbohydrates | .09 | .23* |

*p<.05.

B-vitamin Deficiencies

A preliminary finding that is consistent with low animal protein intake is that vitamin B12 intakes may be low and pyridoxine and riboflavin borderline low. In support of this finding, approximately 7% women, 3% schoolers and 12% toddlers were observed to have macrocytosis of their red blood cells and seven individuals with hypersegmentation of polymorphonuclear (PMN) cell nuclei, four of whom were women.* Clinical evidence that there were vitamin B deficiencies is expressed by such signs as angular stomatitis and atrophic changes of the tongue papillae in a portion of the target individuals (see Table 3).

Table 3
Clinical and hematologic findings consistent with B vitamin deficiencies in schoolers (examined in Jan-June 1984)

| Clinical signs of vitamin B deficiency in schoolers (n=130) | % | |
|---|---|---|
| Atrophic Tongue Papillae | 8.9 - 14.1 | |
| Angular Stomatitis | 2.1 | |
| Cheilosis | 0.7 | |
| Macrocytosis* | | |
| Schooler | 3.2 | |
| Toddlers | 11.6 | |
| Lead Females | 7.0 | (4 women had hypersegmented polymorphonuclear cell nuclei) |

*Based on morphology - observed by 2 senior technicians.

Evidence for iron deficiency was present particularly in the toddlers and pregnant women but also in schoolers (see Table 4). Using ≤ 11 g/dl of hemoglobin as a cut off, 19% of schoolers were anemic; using ≤ 12 g/dl as a cut off, 55% of schoolers were anemic. Six percent (6%) had microcytosis* and 25.6% had low serum ferritin levels (< 10 ng/dl). Thirty-six percent (36%) of schoolers had hookworm ova upon stool examination.

Table 4
Evidence of iron deficiency in schoolers (n=124)

| | |
|---|---|
| Hemoglobin | |
| % anemic | |
| ≤ 11 g/dl | 19.4 |
| ≤ 12 g/dl | 55.6 |
| Red blood cells* | |
| % Hypochromic | 47.6 |
| % Microcytic | 6.0 |
| Serum ferritin | |
| % low (≤10 ng/dl) | 25.6 |
| Hookworm ova in stool | |
| % positive | 36.4 |
| ova/gm stool | 10.0 ± 9.9 |

*Based on examination of morphology by two senior technicians.

Iodine Deficiency

There is evidence of mild or marginal iodine deficiency in the Embu study area. Grade 1+ goiter was found to be present in 18-19% of women and (2+) goiter in 7% (Table 5). In the school-aged children, 5.6% of girls and 2.9% of the boys were found to have 1+ goiter.** A subsample of sera has recently been analyzed for thyroid hormones by radioimmunoassay for serum T4 and Free T4, T3, TSH in the schoolers, toddlers and adults.*** Iodine determinations have been performed on water samples but not on soil or food samples. Water samples from seven water sources in the study area have a mean concentration of 0.25 mg/< (0.1-.50), no access to ocean products and iodized salt was not widely used because of the expense. All the rivers and streams get their water from the melting snows and run off from Mt. Kenya.

No analyses have yet been carried out to correlate thyroid hormone levels with the presence of goiter, Resting Energy Expenditure, linear growth, pregnancy outcome, cognitive function or school performance. This is to be carried out in the near future. Work has been going on at UNC (Marquardt) on the role of iodine deficiency and adult depression. The role of Iodine Deficiency Disease

*Based on RBC morphology as judged by two well trained senior technicians
**1+ goiter observation by palpation and visible only with neck extended
2+ goiter visible with neck in normal position
***These analyses were performed by the Endocrine Assay Laboratory of the MH-CRC under the supervision of Dr. G. Mason at the University of North Carolina, Chapel Hill

(IDD) on cognitive function and growth has been documented (Hetzel).**** The evidence thus far is that there is mild iodine deficiency in the Kenya sample.

Table 5
Evidence of iodine deficiency in schoolers

a) Thyroid Hormone Levels

| | T4 (uU/dl) | Free T4 (uU/dl) | T3 (ng/dl) | TSH (uU/dl) |
|---|---|---|---|---|
| Normal laboratory values* | 5-12 | 0.7-1.7 | 75-175 | < 3.9 |
| % low | 11.7 | 1.0<br>20.0 borderline low (0.7-0.9) | | |

*These are adult norms; values for children may be higher.

b) Thyroid Enlargement in Schoolers and Adult Women

| | | % | | | % | | | % |
|---|---|---|---|---|---|---|---|---|
| Boys n=60 | 1+* | 2.9 | Girls n=73 | 1+ | 5.6 | Adult Women | 1+ | 18.0 |
| | 2+** | 0 | | 2+ | 1.8 | | 2+ | 7.0 |

*1+ thyroid size - palpable, visible only with neck extended.
**2+ thyroid size - visible goiter with neck in normal position.

Qualitative Aspects of the Diet and Toddler Cognitive Function

We feel it is important to start with the toddlers where there is evidence that diet quality correlates more strongly with symbolic play than with total energy intake. All food intake components, total Kcal, total protein, and animal protein and fat, correlated significantly with length and with weight (see Table 6). Animal protein and fat gave the strongest correlations with length. The relationships between fat intake for family SES, home rearing and parental literacy are all statistically significant. Total energy and animal protein intake relate significantly to SES. Fat intake showed neat statistically significant relations to the Bayley Mental test scores. Food intake correlated consistently and significantly with symbolic play (an advanced form of play). This was equally true for total Kcal, animal protein and fat intake. Those toddlers who were more verbally expressive and played more with objects between 15 to 30 mos had better nutritional intakes, particularly of animal protein and fat as expressed by stronger correlations than just Kcal alone. These relationships remained significant even when family backgrounds and home rearing variables were considered (see Tables 7).

****Hetzel, B. (1986) Iodine deficiency disease - a maternal and child health issue. Adv. Int. Mat. Chld. Hlth., 6, 79.

Table 6
Relationship between food intake and anthropometric status of toddlers (n=106)

| Mean daily intake from 18 to 30 mo of age | Length at 30 mo of age | Weight at 30 mo of age |
|---|---|---|
| Total energy (Kcal/day) | 0.32* | 0.25* |
| Protein (g/day) | 0.22* | 0.20* |
| Animal protein (g/day) | 0.32* | 0.08 |
| Fat (g/day) | 0.36* | 0.13 |
| Carbohydrate (g/day) | 0.26* | 0.26* |

*p<0.05 (two-tailed).

Table 7
Relationship between nutritional variables and developmental outcome of toddlers[1,2]

| Nutritional variables | Cognitive measures at 30 months of age | | | | Home observations | | |
|---|---|---|---|---|---|---|---|
| | Bayley Mental score | Play | | | Bayley Motor score | Amount of verb-alization | Amount of play |
| | | Simple | Functional | Symbolic | | | |
| Total kcalories | 0.09 | -0.21* | 0.15 | 0.25* | 0.13 | 0.21* | 0.28* |
| Protein | 0.05 | -0.18 | 0.05 | 0.20* | 0.06 | 0.13 | 0.21* |
| Animal protein | 0.14 | 0.03 | 0.00 | 0.25* | 0.03 | 0.26* | 0.33* |
| Fat | 0.19 | -0.06 | 0.09 | 0.25* | 0.13 | 0.28* | 0.36* |
| Carbohydrates | 0.04 | -0.24* | 0.16 | 0.21* | 0.12 | 0.15 | 0.21* |
| Length | 0.25* | -0.24* | 0.05 | 0.1[illegible] | 0.29* | 0.26 | 0.21* |
| Weight | 0.29* | -0.17 | 0.08 | 0.11 | 0.30* | 0.18 | 0.11 |

[1]Sample size varies because of missing data for some assessments and ranges from 101 to 11(
[2]Appendix C.
*p<0.05 (two-tailed).

Early Nutrition and Later Cognitive Performance: Toddler Follow-up at Age 5 Years (See Appendix E)

In a follow-up study, of the above toddlers, to determine which early nutrition and environmental variables predict cognitive performance at age five years. The strongest relations found were between animal protein and fat intakes from 18 to 30 mos with cognitive scores at five years of age. These two types of nutrients in the diet were most highly correlated with cognitive performance in the children at age five.

In Table 8 are shown the relations between cognitive scores at age five years with animal protein and fat intake in these children when they were between 18 and 24 mos of age.

Using factor analyses, cognitive test scores were associated with a factor reflecting overall food intake from 18 to 24 mos ($r(81) = .24$, $p < .03$) and with a factor reflecting fat and animal protein intake during that time ($r(81) = .33$, $p < .002$).

Table 8
Correlations between nutritional indices and cognitive scores at 5 years of age[1]

| Physical Measures | Initial | 30 Months |
|---|---|---|
| Length | .21 | .25* |
| Weight | .28* | .23* |
| Weight for length | .19 | .17 |
| **Food Intake** | **18-24 Months** | **24-30 Months** |
| KCals | .27* | .03 |
| Protein | .25* | .02 |
| Animal Protein | .33* | .32* |
| Fat | .38* | .25* |
| Carbohydrates | .18 | -.05 |

[1]Appendix D.
*p<.05 (two-tailed).

In a hierarchical regression with fat and animal protein intakes forced into the regression first, fat and animal protein intake continue to contribute to the regression. This suggests that cognitive competence is due mainly to fat and animal protein levels. When environmental and socio-economic variables were controlled for, animal protein still entered the regression and increased the $R^2$ significantly (see Table 9). These analyses strongly suggest a significant association between cognitive outcomes and the level of fat and animal protein in the diet above and beyond family and environmental background.

Table 9
Multiple regression to 5-year cognitive score[1]

| Variables entered | $R^2$ Change from previous step | F | p |
|---|---|---|---|
| Animal Protein | 0.166 | 18.8 | 0.0001 |
| SES | 0.75 | 8.5 | 0.005 |
| Bayley Mental Score 30 months | 0.062 | 7.1 | 0.01 |
| Total $R^2$ | .303 | | |

[1]Appendix D.

Qualitative Aspects of Concurrent Diet and Cognitive Abilities in School Age Children (Appendix E)
The aim of this analysis was to examine the relations between food intake with each of the following: cognitive performance and classroom behavior in school-aged children. Although the main independent variable was energy intake, also examined were the educational resources, family attributes and duration of school experience upon the outcomes. One hundred and thirty-eight (138) schoolers had cognitive testing performed on three occasions from June 1984 to May 1985 and classroom observation on 124, five of whom had no cognitive tests. The mean scores obtained on the three tests were used for

data analysis. Classroom behavior was observed to determine the extent to which children paid attention to class activities using time sampling procedures. For example, how much the child talked to other children, played with objects and were off task or not paying attention to the work at hand. Percent scores were used. The children who were "off task" more frequently had lower cognitive scores and lower school examination grades (see Table 10).

The schoolers were generally thin and small and food intake show that 65% of the boys and 73% of the girls were below the RDAs. As a group, the adequacy of the energy intake was about 93% for the FAO recommended intakes (see earlier discussion of diet). Overall, the mean energy intake correlated highly with protein intake and animal protein was significantly related to fat intakes and both related to overall energy intake. There are significant gender differences in that the males had higher Kcal, protein and fat intakes even on a per kg basis.

All anthropometric and food intake measures show positive and significant correlations with cognitive scores except for height and carbohydrates in the boys (see Table 10). When analyzed by tertiles, the bottom third showed significantly lower food intake from the upper two groups and there were significantly lower cognitive scores for those ingesting low food intake (or the lowest third of the distribution). As with the toddlers, SES was highly correlated with fat and animal protein intakes and it appears that the families with better SES and education provided their children with better nutrition. Clearly, animal protein and fat intakes correlated more strongly and significantly with cognitive outcomes than did overall energy intake even when SES was covaried (see Table 11). Animal protein also entered into a multiple regression equation when duration of schooling is entered first and is the only food intake variable to enter (see Table 12).

Table 10
Correlations between cognitive scores, anthropomorphic measures, food intake, and family characteristics[1]

| | Females (N=60) | | Males (N=73) | |
|---|---|---|---|---|
| | Cognitive Scores | Classroom Behavior | Cognitive Scores | Classroom Behavior |
| Physical Measures | | | | |
| Height for age | .35* | -.14 | .21 | .02 |
| Weight for age | .48* | -.07 | .36* | .07 |
| Weight for height | .47* | -.02 | .37* | .08 |
| Food Intake | | | | |
| Kcalories | .43* | -.27* | .28* | .04 |
| Protein | .46* | -.28* | .28* | .02 |
| Animal protein | .51* | -.26* | .53* | -.03 |
| Fat | .60* | -.28* | .48* | .01 |
| Carbohydrates | .31* | -.23 | .19 | .05 |
| Family Factors | | | | |
| SES | .56* | -.22 | .55* | -.19 |
| Parental literacy | .42* | -.20 | .47* | -.13 |
| Exam Grades[2] | .62* | -.26 | .59* | -.24 |

[1]Appendix E.
[2]Numbers are slightly lower because of some missing data.
*$p<.05$.

Table 11
Correlation between cognitive score and food intake with SES covaried[1]

| | Females | Males | All |
|---|---|---|---|
| | (N=60) | (N=73) | (N=133) |
| Kcalories | .37* | .12 | .18* |
| Protein | .39* | .15 | .21* |
| Animal Protein | .29* | .34* | .31* |
| Fat | .44* | .27* | .31* |
| Carbohydrate | .30* | .07 | .13 |
| SES (When food intake covaried) | .34* | .37* | .38* |

[1]Appendix E.
*$p \leq .05$

Table 12
Multiple regression between nutritional measures, family characteristics, and duration of schooling with cognitive scores

| Variable | $R^2$ Added | F | p |
|---|---|---|---|
| Duration of schooling | .33 | 89.93 | .001 |
| Animal protein | .13 | 36.33 | .001 |
| Weight for age | .05 | 13.87 | .001 |
| SES | .03 | 9.49 | .003 |
| Total $R^2$ | .54 | | |

Classroom Behavior

Not only was insufficient food intake associated with poor performance in cognitive abilities but distractibility and poor ability to concentrate classroom behaviors. In the girls, but not the boys, there were significant negative correlations between food intake and ability to pay attention. Girls with higher Kcal, fat and animal protein intakes were "off task" significantly less than girls with lower intake in these food variables. Thus, girls who were better nourished paid better attention in the classroom and had better performance on cognitive tests and school examinations (see Table 10).

Conclusion

In summary, food intake, then, is related significantly to cognitive skills in Kenyan schoolers, particularly in girls. Those who come from better socio-economic backgrounds had more adequate diets and performed better on cognitive testing. The effects of food intake and nutritional status were still present even after socio-economic status and family background were controlled for. When the toddlers are tested at five years, those that were better-fed as toddlers were more verbal and engaged in more creative play at 30 months than those on poor diets, performed better during age five years. It appears that the fat and animal protein intakes in the children between 18 and 30 mos was particularly related to their cognitive scores at age five years even after controlling for SES status. Although all food intake variables were

positively associated with cognitive outcomes, the fat and animal protein intakes, in particular, showed stronger relationships.

In the school age children, concurrent animal protein and fat intake, particularly in the more poorly-fed girls, appears to play a significant role in the ability to pay attention and in cognitive and school performance. Thus current and past nutritional status play a role.

The findings in the Kenyan study suggest that diet quality is as important for toddlers and schoolers as diet quantity in their cognitive abilities. The diet quality markers that emerge are fat and animal protein. Both fat and animal protein would improve the energy density of the diets, perhaps making it possible for children to obtain more calories in a tolerable volume. These foods could also exert an effect in a more specific way, by providing essential nutrients otherwise low in the diet. Iron deficiency per se does not appear to play a significant role although more analysis on availability must be done. The current hypothesis to be tested in the future is that deficits in other micronutrients may play a role in cognitive function above and beyond energy intake.

Future Work

To go further with quality of diet evaluation in relation to schooler cognitive and school performance, we are awaiting the further work by Drs. Calloway and Murphy on nutrient composition. Further work is now in progress on evaluating the role of possible marginal iodine deficiency and thyroid function on cognitive and school performance. The significance of low B12 and other B vitamin intakes and possibly zinc and iron intake need further work. To date, there have been no striking correlations between hemoglobin and school performance or cognitive function but ferritin levels may show some relationship to these outcomes.

It would seem that in Kenya, low energy intake is an underlying problem and starts early in life as evidenced by stunting which is strongly associated with poor cognitive outcomes. Of course, when diet intake is low, other nutrients are low but the extremely low animal protein and fat intakes because of their contribution of trace metals and minerals, as well as the dense source of energy may be detrimental to the child's growth and cognitive performance. Again, animal protein and fat not only in and of themselves are important sources of nutrients but they are generally associated with higher household SES and educational status. However, when these variables were controlled for fat and animal protein intakes continued on their own to show significant effects on cognitive performance starting in the toddlers and possibly earlier.

# VI. DIETARY QUALITY AND COGNITIVE DEVELOPMENT OF PRESCHOOL AND SCHOOL-AGE CHILDREN IN THE SOLIS VALLEY OF MEXICO

University of Connecticut

## Introduction

The analyses presented in this report were undertaken for the purpose of assessing the relationship of cognitive performance to dietary quality in Mexican children in the Solis Valley. The focus on dietary quality, as contrasted with total energy and protein intake, is dictated by the nature of food availability and dietary patterns in the valley. As in many other areas in developing countries, most of the households in the Solis Valley have access to sufficient food to meet their energy requirements. The dietary staples of maize, legumes, and, to a lesser extent, other cereals, also permit families to obtain protein intakes that meet international recommendations.

However, the typical diet in the Solis Valley is not adequate to support normal physical growth, and children show evidence of growth failure, beginning at an early age and continuing throughout childhood. Infectious disease, particularly diarrhea, plays a part in the growth stunting, but does not account for the magnitude of growth deficit experienced by the children. Moreover, in view of the growth performance of children of Mexican descent raised in the United States, the slower growth of the children in Solis cannot be attributed to genetic factors. Therefore, it is apparent that the malnutrition responsible for growth faltering probably resides in features of the quality of the diet.

## Measures of Dietary Quality

The typical diet of preschool and school-age children in Solis consists primarily of foods of plant origin. Table 1 summarizes the distribution of energy from plant and animal sources. For weaned preschoolers, the mean intake of animal food products is 118 kcal/day, representing 11 percent of total calories. For school-age children the comparable figures are 123 kcal/day, representing 7 percent of total energy. Maize tortillas account for 59 percent of calories from plant sources for preschoolers and 70 percent for school-age children, figures that document the importance of this single food source in the diet. Consumption of fruits and vegetables is low in both groups.

As can be surmised from Table 1, there is a substantial range of consumption patterns in households in the communities of the valley. Some children are proportionately less dependent on maize and consume a greater quantity of other animal and vegetable foods, while others have even more restricted diets than are reflected in the averages. This variation is the basis for the measures of dietary quality.

Measures of dietary quality can be constructed in several ways, including (i) percent of intake from animal food sources; (ii) kcal/day from animal food sources; (iii) grams of protein/day from animal sources; (iv) percent of total calories from maize; or measures of dietary diversity, such as (v) number of different food items in the diet. For the interpretation of these measures, it is important to stress that they all reflect multiple aspects of the diet (ie. intake of micronutrients and fiber, and nutrient availability). Thus, a measure such as "grams of protein from animal food sources" is not necessarily

a measure of protein quality of quantity, but a marker for other dietary constituents, including factors such as intake of phytates.

TABLE 1
Sources of dietary energy for preschool and school-age children

| | Preschoolers (n=79) | | | |
|---|---|---|---|---|
| | Mean Kcals/d | SD | 1st Quartile | 3rd Quartile |
| Kcals from plant sources | 982 | 269 | 821 | 1167 |
| Kcals from animal sources | 118 | 84 | 96 | 147 |
| Kcals from tortillas | 582 | 253 | 404 | 708 |
| | **School-Age Children (n=106)** | | | |
| | Mean Kcals/d | SD | 1st Quartile | 3rd Quartile |
| Kcals from plant sources | 1731 | 423 | 1445 | 2013 |
| Kcals from animal sources | 123 | 87 | 53 | 157 |
| Kcals from tortillas | 1213 | 404 | 947 | 1493 |

Tables 2 and 3 demonstrate the high levels of inter-correlations among the various measures of dietary quality and the lack of association between these measures and total energy intake. In spite of the differences that might be expected between diets of newly weaned toddlers compared to school-age children, the pattern and magnitude of associations is strikingly parallel. The only difference of note is that among preschoolers the number of different items consumed (dietary complexity) is positively associated with quantity of food, whereas there is no relationship between these two characteristics in the diets of school-age children.

**Dietary Quality and Cognitive Performance in Preschool Children**

In the Mexico CRSP project, cognitive development in preschoolers was assessed with the mental component of the Bayley Scales of Infant Development. To avoid potential biases introduced by the use of the standardized scores based on US norms, we have used the total number of items passed, rather than the "highest item" as the basis for comparing children within the sample. Also, since the testing was administered as closely as possible to the time at which a child reached 18, 24 and 30 months, it is unnecessary to adjust for age in intra-sample comparisons. Table 4 demonstrates that at 30 months of age, there is a wide distribution of values in the performance score on the mental component of the Bayley test.

To investigate the relationship of dietary quality to cognitive development we correlated the mean values for selected measures of dietary quality and test performance at 30 months. The mean values were derived from the records of daily intake collected over the course of the year of study, but excluding all days prior to full weaning. For a child who was fully weaned by 18 months of age, the maximum number of daily records on which the average is based would be 24. The analyses were also conducted controlling for the effects of socio-economic status.

TABLE 2
Relationships among dietary quality measures for preschool children

| | Kcal animal sources/day | % Kcal animal sources | Animal protein g/d | % Kcal tortilla | Dietary complexity | Kcal/ day |
|---|---|---|---|---|---|---|
| Kcal animal sources/day | | .93** | .98** | -.71** | .58** | .09# |
| % Kcal animal sources | | | .91** | -.79** | .42** | -.21# |
| Animal protein, g/day | | | | -.70** | .61** | .14# |
| % Kcal tortilla | | | | | -.48** | .26* |
| Dietary complexity[a] | | | | | | .44** |
| Kcal/day | | | | | | |

[a]Defined as average number of individual food items per day.
*p<.02; **p<.0001; #not significant.

TABLE 3
Relationships among dietary quality measures for school-age children

| | Kcal animal sources/day | % Kcal animal sources | Animal protein g/d | % Kcal tortilla | Dietary complexity | Kcal/ day |
|---|---|---|---|---|---|---|
| Kcal animal sources/day | | .93** | .96** | -.70** | .56** | .14# |
| % Kcal animal sources | | | .86** | -.79** | .50** | -.16# |
| Animal protein, g/day | | | | -.59** | .53** | .18# |
| % Kcal tortilla | | | | | -.59** | .21* |
| Dietary complexity[a] | | | | | | .19# |
| Kcal/day | | | | | | |

[a]Defined as average number of individual food items per day.
*p<.05; **p<.0001; #not significant.

TABLE 4
Distribution of Bayley Mental Scores
at 30 months of age

| Score | Number |
|---|---|
| <30 | 4 |
| 30-34 | 11 |
| 35-39 | 13 |
| 40-44 | 32 |
| 45-49 | 17 |
| 50+ | 19 |

(n=96)

Table 5 shows that among the preschool children in this sample, cognitive performance is positively associated with better dietary quality, as measured by the percent contribution of animal foods to the diet. The significant negative association between performance and percent of energy from tortillas reinforces the first finding. The lack of association between total energy or protein intake and dietary complexity (which is associated with total intake in this age group) is also documented in this table.

The interpretation of a diet quality-cognitive development association as an artifact of co-variance between diet quality and SES is not supported by the results of the partial correlations. That is, when socio-economic status is statistically controlled, there is no diminution in the magnitude of the association between the diet and cognitive measures.

TABLE 5
Relationships of dietary measures to cognitive performance of preschoolers at 30 months of age

| | Bayley Mental Score | |
|---|---|---|
| | Correlation | Partial correlation controlled for SES |
| % Kcal from animal sources | .29** | .24** |
| % Kcal from tortillas | -.31*** | -.31*** |
| Total kcal | NS | NS |
| Total protein | NS | NS |

**p<.01; ***p<.005.

Dietary Quality and Cognitive Performance in School-Age Children

In the Mexico CRSP project, cognitive development in school-age was assessed with a number of different measures taken primarily from the WISC-R. The test protocol also included the Raven's Progressive Matrices Task and the Peabody Picture Vocabulary Test, modified for use in Mexico. As with the preschool children, we have used raw scores rather than standardized scores to make comparisons within the sample. Table 6 shows the substantial distribution of values on these various indices of cognitive development.

TABLE 6
Cognitive test scores of Solis children 7-9 years of age

| Cognitive measure | Mean | SD |
|---|---|---|
| Vocabulary | 24.8 | 4.6 |
| Arithmetic | 8.9 | 2.9 |
| Digit span | 3.7 | 1.4 |
| Mazes | 13.4 | 6.3 |
| Ravens | 12.8 | 2.9 |
| Block design | 7.7 | 6.3 |

To assess the relationship of cognitive development to dietary quality among the school-age children we applied the same analysis procedures that were used with the preschoolers. Mean values were derived from the diet records, collected twice per month over the year of study, and correlated with the performance scores obtained near the end of the study. Then partial correlations, controlling for SES, were also calculated. The results are presented in Table 7 and Table 8.

TABLE 7
Correlations of dietary measures and cognitive performance of school-age children (n=103)

| | Cognitive measures | | | | | |
|---|---|---|---|---|---|---|
| | Raven's Matrices r | Digits (total) r | Vocabulary r | Block Design r | Mazes r | Arithmetic r |
| % Kcal from animal sources | .33**** | .31**** | .32**** | .39**** | .23*** | .35**** |
| % Kcal from tortillas | -.35**** | -.25*** | -.32**** | -.47**** | -.28*** | -.29**** |
| Dietary complexity | .21** | .27*** | .26*** | .33**** | .23** | .26*** |
| Total kcal | | | | | | |
| Total protein | | | | | | |

*p<.05; **p<.01; ***p<.005; ****p<.001.

TABLE 8
Partial correlations of dietary measures and cognitive performance of school-age children, controlling for SES (n=103)

| | Cognitive measures | | | | | |
|---|---|---|---|---|---|---|
| | Raven's Matrices r | Digits (total) r | Vocabulary r | Block Design r | Mazes r | Arithmetic r |
| % Kcal from animal sources | .27*** | | | .31*** | | .20* |
| % Kcal from tortillas | -.29*** | | -.17* | -.41*** | -.17* | |
| Dietary complexity | | | | .23*** | | |
| Total kcal | | | | | | |
| Total protein | | | | | | |

*p<.05; **p<.01; ***p<.005.

Parallel to the preschoolers, the results of the simple correlations show positive associations between cognitive development and dietary quality. However, in this age group, the relationship between socio-economic status and diet as it affects nutrition is much stronger. When socio-economic status is statistically controlled, a number of the correlations are reduced to the point that they are no longer significant.

One cannot conclude, however, that the simple correlations are merely artifacts of an association between socio-economic status and diet. Rather, what we see are the effects of a complex interaction involving economic resources, food selection, dietary intake, household-generated stimulation, and other factors. The nature of these analyses do not provide a basis for elevating one factor (eg. socio-economic status) to causal primacy over the other (dietary quality). Also, it should be noted that in the case of the Raven and Block designs tests the effect of controlling for SES are negligible, and the effects on arithmetic and maze performance are mixed.

Conclusions

The correlational studies presented above document statistically significant relationships between measures of dietary quality and cognitive performance in both preschool and school-age children in the Solis Valley. The lack of correlation between total energy and protein intake and the measures of development utilized in the study suggest that the forms of malnutrition in this region are more subtle than the frank manifestations of marasmus and kwashiorkor that have become synonymous with hunger and malnutrition in the public mind.

The scientific and policy implications of the CRSP results to date require careful study, but they the basis for further analysis. Detailed analysis of the dietary constituents that underlie the global measures of "quality" utilized in these analyses are required as part of an effort to identify the possible mechanisms and factors that may account for the observed patterns of association.

At the same time, a fuller analysis of the household data-especially of the ways in which maternal health, diet, physical and social activity relate to psychological development of the infant, preschool and school-age children-will also provide important insights into the dynamics that underlie the relationships reported here.

Ultimately, carefully designed intervention programs will be necessary to provide more definitive answers about the specific factors that are involved, but much remains to be learned through further analysis of the rich data base of the CRSP project.

# VII. ANTHROPOMETRIC CHARACTERISTICS OF SPOUSES IN RURAL HOUSEHOLDS IN EGYPT, KENYA, AND MEXICO: INDICATORS AND IMPLICATIONS

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The efficiency of programs intended to ameliorate problems of malnutrition would be improved if the population affected or at risk could be identified with better precision and reliability and at lower cost than is now the case. Anthropometric characteristics often are used as a proxy for inadequate or excessive food intake, even though it is recognized that environmental and genetic factors confound the relationship between intake and state. The CRSP has provided data on an array of anthropometric and potentially confounding variables. These data allow exploration of relationships between measures of body size and composition within individuals, and thus, identification of the parameters that may have widest utility. Comparisons between members of a household may determine, further, if the characteristics of one person can serve as a reliable indicator of those of other members of the family. This report presents information on the male and female adults who were heads of households.

## Anthropometric Measurements and Derived Values

According to the research plan, adult height and head circumference were to be measured at least once, mid-upper arm circumference and skinfold thicknesses every three months, and body weight monthly. Methods of measurement and selection of equipment were agreed upon collectively by the project investigators, one of whom (GH) provided the manual used by all. Project staff field-tested methods and trained observers on site during the year prior to longitudinal data collection. Each project used paired observers as a method of quality control and implemented controlled protocols to examine the reliability of selected measurements.

Subjects were measured and weighed without shoes and lightly clothed. The basic research plan called for measurement of biceps and triceps skinfold thickness. All projects measured subscapular skinfold thickness as well, but the sample N is small in Egypt, where modesty was a barrier. Mexico also measured suprailiac skinfolds on all subjects and Kenya recorded suprailiac values for women only.

For all three project sites, only spousal couples whose members were both determined to have at least one valid height and weight measurement have been included for analysis. Automated outlier range checks were performed on all height, weight, and head circumference parameters; mid-upper arm and skinfold parameters were checked visually.

Individual subject characteristics have been represented as median values over all valid measurements; medians are a more robust measure of central tendency in that they are less influenced by the magnitude of outliers. Only one daily measurement was allowed to contribute to each subject median. Mean daily values were precomputed for multiple measurements occurring within a single day.

For female subjects, all weight, mid-upper arm and skinfold parameters determined to be measured during the second or third trimester of pregnancy or the first or second trimester of lactation were excluded. In the event that this restriction eliminated all observations for any subject, it was relaxed to include the last observation within the second trimester of lactation and, if

required, relaxed again to include the second trimester of pregnancy. For the Kenya and Egypt projects pregnancy and lactation periods were determined by identifying all infant births and miscarriages. For the Mexico project, the determination was made by the staff at the University of Connecticut based upon females' physiological status data and records of weaning.

Due to a potential change in posture, height measurements taken during the third trimester of pregnancy were excluded for female subjects whenever other measurements were available. Head circumferences were computed from all observations, regardless of reproductive status.

The Body mass index (BMI), also called Quetelet-Score was calculated by dividing body weight by median height squared ($kg/m^2$).

Z-scores for body weight, height and body mass index were calculated from U.S. norms developed by the National Center for Health Statistics (1987) from the 1976-80 HANES data.

Body fat was estimated from skinfold thickness using formulas developed by Durnin and Womersley (1974) to predict body density, and Siri's (1961) formula to calculate fat from density. Density was calculated from median values for each of the three skinfold thicknesses separately and in all possible combinations, and using both age-specific and general equations for adult males (age 17-72 years) and females (age 16-68 years). No one formula appeared to produce consistently higher or lower values across locations or sex groups, nor was there appreciable difference between values calculated from age-specific or general adult formulas. Subsequent analyses were carried out using percentages of fat derived from a combination of triceps, biceps, and subscapular skinfold measures (where the N for Egypt is low) and from triceps values only, calculated according to the general adult equations.[1] Lean body mass was calculated as the difference between body weight and the weight of fat estimated from these percentages.

Arm muscle area was calculated from mid-upper arm circumference and triceps skinfold thickness according to Frisancho (1981).[2] Values were not corrected for bone.

All correlations reported herein are Pearson product-moment correlations. Intra-spousal associations are reported as partial correlations, having been controlled

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[1]Density = C - M log skinfold, where

| | Males | Females |
|---|---|---|
| Triceps: | C = 1.1143 | C = 1.1278 |
| | M = 0.0618 | M = 0.0775 |
| Biceps, Triceps and Subscapular: | C = 1.1689 | C = 1.1543 |
| | M = 0.0793 | M = 0.0756 |

$$\% \text{ Fat} = \frac{4.95}{\text{Density}} - 4.50 \times 100$$

[2]Arm Muscle Area = $\frac{[\text{MUAC} - (P \times \text{triceps skinfold thickness})]}{4P}$

for the age of each member. Only statistically significant correlations ($p < .05$) are reported.

Anthropometric Characteristics of the Three Populations (Tables 1 and 2)

Age. Mean ages of men and women were approximately 35 and 33 years, respectively, in both Kenya and Mexico; Egypt men and women were a bit younger, 36 and 30 years of age. Most women in the sample populations were between 20 and 40 years of age. Male's ages centered between 25 and 50 years but there was a wider spread into older ages than for women; the difference between maximum ages of women and men was about 20 years in all three sample populations. The age of spousal pairs was closely correlated ( $r = .74$ to $.80$, $p = .0001$) and in almost all couples the male was older (mean differences in spousal age of 5.5 ± 5.2 years in Kenya, 4.6 ± 4.9 years in Mexico and 5.6 ± 4.7 years in Egypt).

Height. There was a small difference in stature between locations, but mean height was well below U.S. norms in all locations. The mean Z-scores for male heights are -1.26 in Egypt, -1.45 in Mexico and -1.55 in Kenya, i.e. the average height (1.65 to 1.68 m, 65-66 in.) was one and a quarter to one and a half standard deviations below the U.S. average or, expressed another way, average height in Egypt was near the U.S. 10th centile and average height of Kenya and Mexico males was below the 10th centile. Mean height of women (1.53-1.56 m, 60-61 in) was also below the U.S. average. Z-scores indicate that height of women was less depressed, relative to U.S. norm, than that of men in Egypt and Kenya but the situation was reversed in Mexico.

The possibility that height and age were correlated, indicative of a secular trend in recent decades, was examined. A significant negative correlation between male height and age was found in the Mexico sample ($r = -.18$, $p = .01$) and the association just missed significance in Kenya males ($r = -.11$, $p = .06$). There was no relationship between male height and age in Egypt, nor between female height and age in any location.

Weight. Mean body weights differed between locations much more than did heights, and weight was also more variable within groups (CVs 12-18% in contrast to height CVs of 3-4%). The Kenya population weighed the least (men 55 kg (121 lb), women 51 kg (112 lb)); the Egypt sample was the heaviest (men 71 kg (156 lb), women 64 kg (141 lb)); Mexico weights were intermediate (men 66 kg (145 lb), women 58 kg (130 lb)). Group mean weights were below U.S. norms but except for Kenya males, whose weight was notably low (Z-score -1.84, much below the U.S. 3rd centile), the Z-scores for weight were less depressed than scores for height.

Relationships between weight and age also are different from those between height and age. Weight and age were not correlated in men nor in Kenya women, but these parameters were strongly correlated in Mexico and Egypt women ($p < .001$).

Weight for Height, Body Mass Index. As expected, body weight and height were related in all three locations. The correlation was slightly stronger in males than females and diminished with increasing body weight across these locations. (For example, correlation coefficient of height and weight for Kenya males is 0.63 and for Egypt males, 0.39, but $p = .0001$ in both cases). A convenient way to look at these relationships is by the computed body mass index. BMI was strongly associated with weight in the three locations ($r = .78$-$.93$) but essentially was unrelated to height (correlated only in Kenya women, $r = .13$, $p = .03$).

**Table 1.** **Median Values for Anthropometric Measurements in Adults and Z-scores for Weight, Height and Body Mass Index (Mean ± SD)**

| Measurement | | Kenya | | Mexico | | Egypt | |
|---|---|---|---|---|---|---|---|
| | (N)[a] | Men (274) | Women (274) | Men (199) | Women (199) | Men (193) | Women (193) |
| Age | yr. | 38.2 ± 7.7 | 32.8 ± 6.0 | 37.4 ± 8.0 | 33.0 ± 7.1 | 35.5 ± 7.3 | 29.9 ± 6.4 |
| Weight | kg. | 55.3 ± 6.8 | 51.1 ± 8.1 | 66.1 ±10.1 | 58.4 ± 9.5 | 71.4 ± 12.0 | 64.0 ± 11.6 |
| Height | m. | 1.65 ± .06 | 1.55 ± .06 | 1.66 ± .06 | 1.53 ± .05 | 1.68 ± .06 | 1.56 ± .05 |
| Body Mass Index | $kg/m^2$ | 20.2 ± 1.9 | 21.3 ± 2.7 | 23.9 ± 3.1 | 24.9 ± 3.8 | 25.4 ± 3.9 | 26.4 ± 4.7 |
| Skinfold Thickness | mm. | | | | | | |
| Triceps | | 6.2 ± 2.8 | 16.7 ± 6.8 | 7.6 ± 3.9 | 17.0 ± 5.1 | 11.1 ± 6.4 | 21.8 ± 8.5 |
| Biceps | | 3.0 ± 0.8 | 6.1 ± 3.8 | 3.1 ± 2.2 | 7.5 ± 3.6 | 5.9 ± 3.1 | 11.4 ± 6.5 |
| Subscapular | | 8.0 ± 2.8 | 13.6 ± 6.4 | 13.0 ± 6.6 | 26.5 ± 9.8 | 11.3 ± 6.2[a] | 14.9 ± 7.0[a] |
| Suprailiac | | --- | 8.4 ± 6.1 | 14.9 ± 7.6 | 26.6 ± 9.4 | ---- | ---- |
| Circumference | cm | | | | | | |
| Midupper Arm | | 25.7 ± 1.9 | 26.3 ± 2.9 | 28.2 ± 2.3 | 28.0 ± 2.9 | 27.1 ± 2.9 | 26.8 ± 3.5 |
| Head | | 55.5 ± 1.5 | 53.8 ± 1.5 | 55.8 ± 1.5 | 53.3 ± 1.4 | 55.5 ± 2.2 | 53.6 ± 2.2 |
| Z score[b] | | | | | | | |
| Weight | | -1.84 ± 0.52 | -0.95 ± 0.55 | -1.02 ± 0.77 | -0.45 ± 0.63 | -0.61 ± 0.90 | -0.02 ± 0.77 |
| Height | | -1.55 ± 0.91 | -1.30 ± 0.90 | -1.45 ± 0.85 | -1.54 ± 0.80 | -1.26 ± 0.90 | -1.16 ± 0.79 |
| Body Mass Index | | -1.41 ± 0.51 | -0.57 ± 0.50 | -0.40 ± 0.80 | 0.08 ± 0.67 | -0.04 ± 1.01 | 0.43 ± 0.83 |
| Body fat[c] | % | | | | | | |
| 3 skinfolds | | 11.6 ± 4.3 | 26.5 ± 6.0 | 15.5 ± 7.0 | 31.9 ± 5.7 | 18.2 ± 7.5[a] | 31.2 ± 6.0[a] |
| triceps only | | 13.9 ± 4.2 | 28.0 ± 6.2 | 15.7 ± 5.6 | 28.8 ± 4.9 | 19.8 ± 6.7[a] | 32.2 ± 6.1[a] |
| Lean mass[c] | kg | | | | | | |
| 3 skinfolds | | 48.6 ± 5.1 | 37.2 ± 3.9 | 55.3 ± 6.0 | 39.2 ± 4.3 | 57.4 ± 7.6[a] | 43.6 ± 5.7[a] |
| triceps only | | 47.4 ± 5.0 | 36.4 ± 4.0 | 55.3 ± 6.5 | 41.1 ± 5.1 | 56.3 ± 7.5[a] | 42.5 ± 5.2[a] |
| Arm muscle area[d] | $cm^2$ | 45.0 ± 6.3 | 35.4 ± 5.1 | 53.1 ± 7.7 | 41.1 ± 6.7 | 44.6 ± 9.7 | 32.1 ± 6.9 |

a N of parameters except head circ. (Kenya M 194, F 265; Mexico M 187; Egypt M 34, F 51) and skin folds (Kenya M 273; Mexico F 203; Egypt M triceps & biceps 152, subscap 48 and F triceps & biceps 172, subsc 45)

b Computed Z score based on U.S. reference data for height and weight from National Center for Health Statistics, 1987.

c Body fat calculated from Durnin and Womersley, 1974. Lean mass = body weight - (body wt x (% body fat/100)

d Calculated from Frisancho, 1981.

**Table 2.** **Correlation Between Anthropometric Parameters of Adults in Kenya, Mexico and Egypt[a]**

| | Country[b] | Height | Body Mass Index | <------- Skinfolds -------> Triceps | Biceps | Subsc. | Midarm Circum. | Head Circum. | Arm Muscle Area | % Body Fat Three Skinfolds | Triceps |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MALES | | | | | | | | | | | |
| Weight | K | .63 | .78 | .50 | .50 | .52 | .73 | .49 | .59 | .55 | .51 |
| | M | .51 | .88 | .66 | .60 | .68 | .83 | .52 | .62 | .68 | .64 |
| | E | .39 | .90 | .57 | .55 | .61 | .82 | .40 | .50 | .63 | .58 |
| Height | K | | | | .15 | --- | .16 | .28 | .17 | --- | --- |
| | M | | | | --- | .15 | .24 | .35 | .20 | --- | .15 |
| | E | | | | --- | --- | --- | --- | .23 | --- | --- |
| Body Mass Index | K | | | .61 | .52 | .61 | .81 | .38 | .62 | .64 | .60 |
| | M | | | .68 | .64 | .73 | .84 | .40 | .62 | .73 | .66 |
| | E | | | .68 | .65 | .72 | .82 | .35 | .42 | .72 | .66 |
| Triceps Skinfold | K | | | | .82 | .85 | .52 | .32 | --- | .94 | .96 |
| | M | | | | .81 | .85 | .61 | .30 | --- | .92 | .96 |
| | E | | | | .89 | .64 | .58 | --- | --- | .89 | .96 |
| FEMALES | | | | | | | | | | | |
| Weight | K | .58 | .88 | .74 | .68 | .74 | .85 | .52 | .58 | .74 | .69 |
| | M | .41 | .92 | .71 | .69 | .80 | .88 | .52 | .76 | .68 | .64 |
| | E | .25 | .93 | .78 | .74 | .62 | .89 | .21 | .53 | .83 | .74 |
| Height | K | | .13 | .18 | --- | .15 | .26 | .46 | .25 | .17 | .17 |
| | M | | --- | --- | --- | --- | .17 | .29 | .20 | --- | --- |
| | E | | --- | --- | --- | --- | --- | --- | --- | .30 | --- |
| Body Mass Index | K | | | .79 | .76 | .81 | .88 | .38 | .56 | .81 | .74 |
| | M | | | .75 | .73 | .83 | .89 | .44 | .75 | .81 | .73 |
| | E | | | .78 | .76 | .68 | .89 | --- | .51 | .82 | .74 |
| Triceps Skinfold | K | | | | .87 | .84 | .86 | .31 | .22 | .98 | .97 |
| | M | | | | .87 | .79 | .81 | .31 | .41 | .91 | .96 |
| | E | | | | .83 | .48 | .80 | --- | --- | .89 | .97 |

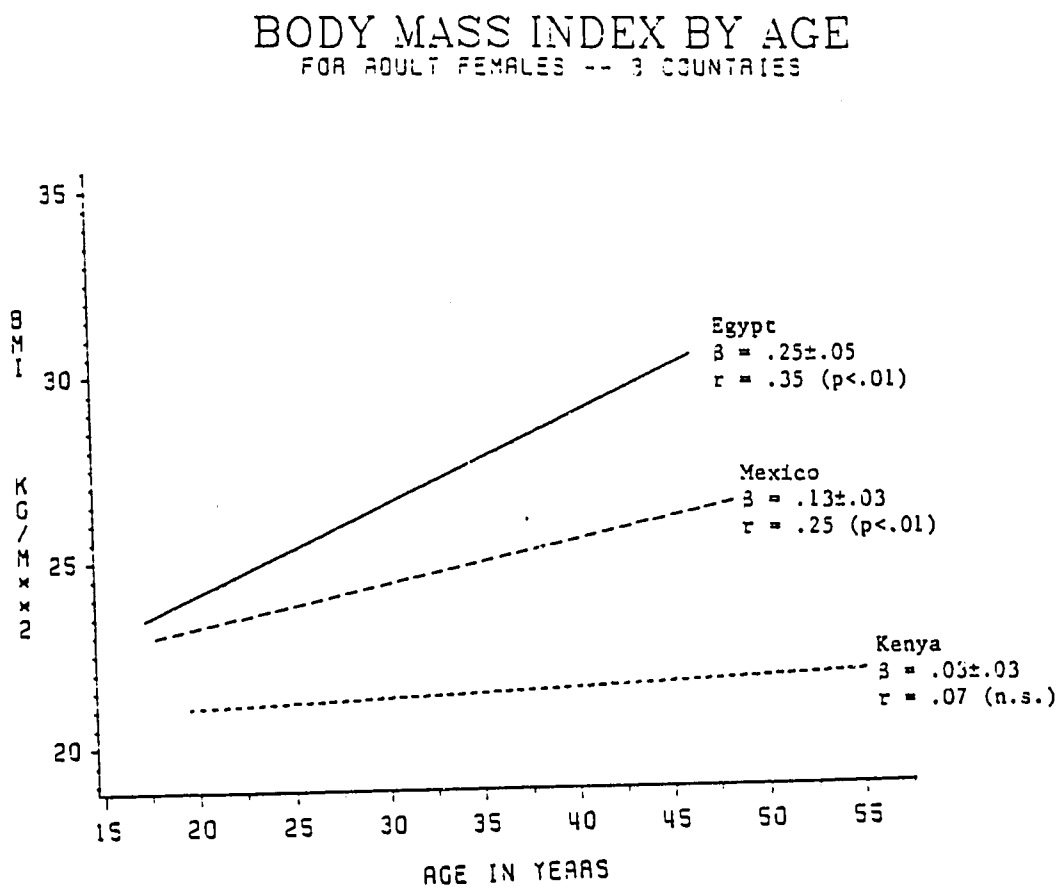
[a] N's are as given in Table 1. All values shown are significant ($p<.05$).
[b] K=Kenya, M=Mexico, E=Egypt

BMI standards, for classification of under- and overweight in the U.S., are set at approximately the 15th and 85th centiles of persons aged 20-29 years in the U.S. population. The cut-off points increase slightly with age but for the project populations values of 20 through 26 would be appropriate.

In Kenya, BMI was below 20 in 32% of women and 52% of men; values were above 26 in only 7% of women and 1% of men. Z-scores of BMI were -1.41 and -0.57 for men and women, respectively, and describe a generally thin population. At the other extreme, 2% of women in Egypt and 4% of men had a BMI below 20; BMIs of 35% of men and 45% of women were above 26. Z-scores for BMI in Egypt were close to U.S. norms (-.04 for men and .43 for women). Although there is substantial variation within the populations, on average men in Egypt would match the weight of the U.S. population of their height and women would be slightly heavier. Z-scores of BMI in the Mexico sample were -0.46 for men and 0.08 for women, bridging values for Kenya and Egypt.

Correlations between BMI and age reflect the relationship of weight and age. (See Figure 1). In Kenya, BMI and age were not correlated in either sex. In Mexico and Egypt, male BMI did not vary with age, but BMI of women increased significantly with age. Regression equations describing the relationship in women are: Egypt BMI = 18.8 + .25 (age, yr); Mexico BMI = 20.8 + .13 (age, yr). As the Beta values indicate, the change in female BMI with age was much greater in Egypt than in Mexico.

Figure 1



Mid Upper Arm Circumference. Differences in mean mid-upper arm circumference (MUAC) between countries were small, but interesting in relation to body weight. MUAC was closely correlated ($p < .0001$) with body weight and BMI in each country/sex group and the correlations were a bit closer for women ($r = .85$-$.89$) than for men (0.73-0.84). MUAC was a more uniform characteristic than was body weight in each group (CV's in Mexico were, for example, 8 and 15% for male MUAC and body weight and 10 and 16% for respective female values). Looking across countries, however, mean MUAC did not follow the rank order of mean weight; MUAC was greater in Mexico than in Kenya, as body weight would predict, but mean MUAC in Mexico was greater than in Egypt where mean body weight was heavier.

Head Circumference. There was very little difference in head circumference between populations (maximum difference in means was 0.5 cm) and very little variability within groups (CV's of 2-4%). Nonetheless, head circumference correlated significantly with body weight in all groups, with BMI in all but Egypt women and with height in Kenya and Mexico populations. Correlations of weight and BMI with head circumference were lower than those with MUAC but associations between height and head circumference, where they existed, were stronger than the correlations with MUAC.

Skinfold Thickness and Body Fat. Measures of skinfold thickness at the different body sites were closely correlated. Skinfolds were consistently greater in women than in men. Biceps and triceps measures were similar in the Kenya and Mexico populations, both in men and women, but the subscapular skinfold was much thicker in Mexico. The difference in suprailiac skinfold thickness between women in Kenya and Mexico is particularly striking (8.4 and 26.6 mm) respectively. In Egypt, biceps and triceps skinfolds are thicker than in the other countries. Subscapular skinfold measures, recorded for about 25% of the Egypt men and women, are inconsistent with expectations based on the comparison between Kenya and Mexico values, and the correlation between these and other skinfold measures within Egypt adults is much lower than in the other countries. This difference may be artifactual, due to methodology, or may indicate a valid difference in body fat patterning.

Percentage of body fat calculated from triceps skinfold measures was lowest in Kenya. Even in this generally lean population the body fat of women (28%) was twice that of men (14%). Comparable values for Mexico women and men were only slightly higher (29% and 16%) but figures for Egypt, especially the men (20%), were substantially higher.

Although skinfold thicknesses at various body sites are strongly correlated, the magnitude of change with increasing fatness is not uniform among sites. For the two populations where the data set is complete, the difference in percentage body fat calculated from three skinfolds versus only triceps moves in the direction predictable from the difference in thickness of the subscapular skinfold, i.e. estimated percentage of fat is negligibly lower in Kenya, for both men and women, and higher in Mexico women. These differences are not significant and the two estimates of percentage fat are very closely correlated ($r > 0.9$, $p < .0001$) in all three country locations.

A fourth skinfold measure, suprailiac, is available for women in Kenya and Mexico. Inclusion of this measure has no effect on the estimate of fat in Kenya women (mean 28%) but predicts a higher percentage in Mexico women (mean 36%).

The percentage of body fat is calculated from body density which is estimated from skinfold thickness using equations derived from a large series of European subjects (Durnin and Womersly, 1974). Any factor that causes density of the lean body compartment to differ from that on which the equations are based will introduce an unknown error. The factor that is most likely to affect density in the present populations is skeletal mass. There is no information at hand from which to estimate the probability of such differences. Differences in fat patterning, alluded to above, would also vitiate the validity of the predictive formulas.

Lean Body Mass and Arm Muscle Area. Lean body mass (LBM) is estimated by subtracting the amount of body fat, calculated as described above, from the median body weight. LBM of Kenya men and women was about 15% below that of the Mexico groups. Despite the difference in body weights between the Mexico and Egypt populations, there was relatively little difference (<5%) in LBM, most of the weight differential being due to fat.

The only other indicator of LBM available is the computed arm muscle area. These estimates of leanness are not entirely independent because both utilize the triceps skinfold measure in the computation. The two measures are closely correlated in all groups ($r = .64$-$.75$, $p < .0001$). As was the case in comparing MUAC and body weight across countries, the rank order of arm muscle area among countries was not the same as for LBM. Although LBM was about the same in Mexico and Egypt, arm muscle area was much larger in Mexico. The differences in arm muscle area between Mexico and Kenya did, however, follow the relationship in LBM. These relationships suggest heavier upper-body work patterns in Mexico and Kenya than in Egypt, for both men and women.

Spousal Correlations (Table 3) Because height of Mexico males was negatively correlated with age and weight of Mexico and Egypt females was positively correlated with age, relationships between spousal pairs were evaluated after removal of age. Correlations between spousal parameters are not as strong as those within sex groups but there is surprising consistency in the three very different populations. Height was not correlated between spouses in any country but spousal weights ( $r = .13$-$.17$) and MUACs ($r = .14$-$.23$) were significantly related ($p < .05$). Correlations between BMIs and triceps skinfold thicknesses between spouses were more robust ($r = .22$-$.33$) in Kenya and Mexico than the correlations with weight and MUAC, but these parameters were not related in Egypt spouses. Male MUAC is correlated with female BMI, as well as MUAC, in all locations. Arm muscle area of spouses is correlated only in the Mexico population. These findings suggest that fatness is a commonly shared characteristic, reflecting one or more household variables. Arm muscle development may be a common characteristic as well, but the relationship was found only in Mexico.

Preliminary Evaluation of Anthropometric and Cognitive Characteristics (Table 4). Projects have not yet reported on cognitive measures of adults in a way that permits across-project comparisons. Very preliminary examination of raw scores for tests administered in the three locations suggests that the factor(s) that affect body fatness also are related to cognitive test performance. Kenya cognitive scores of both men and women on one or more tests were significantly correlated with height, weight, BMI, percentage of body fat and MUAC. In Mexico, correlations existed between scores on two tests (the similarities test was not administered) percentage fat of both sexes and MUAC of women. Significant correlations were found only for male scores in Egypt, most consistently for BMI and MUAC.

**Table 3.** **Correlation Between Anthropometric Parameters of Spousal Pairs in Kenya, Mexico and Egypt[a]**

| FEMALE | Country[b] | MALE Weight | Body Mass Index | Triceps Skinfold | Midarm Circum. | Arm Muscle Area |
|---|---|---|---|---|---|---|
| Weight | K | 0.17 | 0.23 | 0.34 | 0.23 | ---- |
| | M | 0.13 | 0.16 | 0.17 | 0.20 | 0.15 |
| | E | 0.16 | ---- | ---- | 0.23 | ---- |
| Body Mass Index | K | 0.17 | 0.25 | 0.34 | 0.25 | 0.11 |
| | M | 0.17 | 0.22 | 0.22 | 0.24 | 0.16 |
| | E | ---- | ---- | ---- | 0.22 | ---- |
| Triceps Skinfold | K | 0.16 | 0.25 | 0.33 | 0.26 | 0.12 |
| | M | 0.19 | 0.23 | 0.27 | 0.24 | 0.12 |
| | E | ---- | ---- | ---- | ---- | ---- |
| Mid-arm Circumference | K | 0.14 | 0.25 | 0.35 | 0.23 | ---- |
| | M | 0.15 | 0.18 | 0.17 | 0.22 | 0.17 |
| | E | ---- | ---- | ---- | 0.14 | ---- |
| Arm Muscle Area | K | ---- | 0.12 | 0.18 | ---- | ---- |
| | M | ---- | ---- | ---- | 0.14 | 0.16 |
| | E | ---- | ---- | ---- | ---- | ---- |

[a] N as in Table 1. Correlation coefficients have been controlled for male and female age. All values shown are statistically significant ($p<.05$); for values of the order 0.2 and above, $p<.001$.

[b] K=Kenya, M=Mexico, E=Egypt

**Table 4 (Preliminary)[a]: Correlation Between Anthropometric Parameters and Cognitive Test Scores of Adults**

| | | | | <----------Men----------> | | | | <----------Women----------> | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | Women | Measure | Digit Span | Raven's Matrices | Block Design | Similarities | Digit Span | Raven's Matrices | Block Design | Similarities |
| Kenya | 238 | 243 | Height | | .14 | .22 | | .15 | | | .14 |
| | | | Weight | .15 | .29 | .31 | .19 | .18 | .15 | .16 | .14 |
| | | | BMI[b] | | .26 | .22 | .22 | .14 | .13 | | .13 |
| | | | % Fat[b] | .27 | .39 | .36 | .25 | .14 | .17 | | .13 |
| | | | MUAC[b] | | .20 | .19 | .14 | .16 | .13 | .13. | .14 |
| Mexico | 156 | 170 | % Fat | .24 | | .18 | ---- | .21 | | | ---- |
| | | | MUAC | | | | ---- | .19 | | | ---- |
| Egypt | 54 | 90 | Weight | | | | .53 | | | | |
| | | | BMI | | | .29 | .52 | | | | |
| | | | % Fat | | | | .41 | | | | |
| | | | MUAC | .34 | | .35 | .54 | | | | |

a Projects have not yet archived revised cognitive scores. There are significant negative corrleations between age and cognitive scores in Kenya and Mexico which have not yet been taken into account.

b BMI=Body Mass Index (kg/m$^2$); % fat calculated from triceps skinfold thickness according to Durnin and Womersly, 1974; MUAC=mid-upper arm circumference

**Implications**

Food consumption data reported by the three projects indicate that food energy intake was limiting in Kenya during the period of study and that food quality, in terms of overall nutrient supply, was low in both Kenya and Mexico. The food situation was, perhaps, not ideal in Egypt but it was clearly better than in the other two locations.

Relationships between intake and adult size can be explored in detail when analytical files on food intake are completed. Based on evidence at hand, however, it seems clear that measurement of women's body weight and height may be a simple way to assess overall food availability. In the populations where the food supply appeared to be sufficient, BMI of women increased with age, and the extent of increase was greater in Egypt where work requirements, and hence energy need, also may have been lower. A survey of BMI of women, in the types of communities the CRSP has examined, would constitute a rapid, low-cost method of indicating whether or not sufficient food has been available over time. The possibility warrants examination by others who have or can obtain suitable data.

The question of why women's weight changed significantly over time and men's did not is interesting. It is true that deposition of fat is a sexually dimorphic characteristic in animals generally, but in privileged populations both males and females tend to gain some fat and lose lean mass with advancing age. Percentage of body fat in the men, although less than in women and unchanged across ages, did reflect the different food conditions in the three countries, i.e. the percentage of body fat of men in Egypt was higher than in Mexico, which was higher than in Kenya. Whatever accounts for the sex differences in weight trends, it is difficult to postulate, as is frequently done in developed countries, that child-bearing is a factor. Projects have reported almost equally low weight gains during pregnancy in the three countries and parity is about the same in all three groups.

Setting age aside, body weight and arm circumference of husbands and wives are significantly correlated. A correlation in spousal fatness also has been reported in the U.S. (Garn et al., 1980). Fatness, reflecting energy balance in the household, probably is associated with a number of social and economic variables which have not yet been assessed. The CRSP data ultimately will allow examination of intakes of essential nutrients and morbidity, neither of which has been studied in this way heretofore.

The preliminary evidence linking body fatness and cognitive performance is exactly that. Project psychologists have not yet archived revisions of the adult data base and the multiple factors that may covary with cognitive performance have not been considered at all. What this preliminary finding does indicate, however, is that relief of the dietary factors that appear to constrain body conformation of adults is associated with better mental performance. It is yet to be determined which comes first.

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APPENDIX A

# Vitamin B-6 status of Egyptian mothers: relation to infant behavior and maternal-infant interactions[1-4]

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ABSTRACT Functional consequences of marginal maternal vitamin B-6 status for behavior of the neonate and for mother-infant interactions at age 3–6 mo were assessed by a double-blind procedure. In 27 of 70 Egyptian village women studied, vitamin B-6 concentration of their milk was considered indicative of poor maternal vitamin B-6 nutriture. Neonatal behavior, quantified by the Brazelton Neonatal Behavioral Assessment Scale, showed that consolability, appropriate build-up to a crying state, and response to aversive stimuli were significantly correlated with maternal vitamin B-6 nutriture. Naturalistic observational procedures, used twice monthly with infants aged 3–6 mo, indicated that mothers assessed as having marginal vitamin B-6 status were less responsive to their infants' vocalizations, showed less effective intervention to infant distress, and were more likely to use older siblings as caregivers than were mothers of better vitamin status. We conclude that vitamin B-6 was a factor influencing both the behavior of the mother and her infant. *Am J Clin Nutr* 1990;51:1067–74.

KEY WORDS Vitamin B-6, infant behavior, maternal-infant interactions, human milk, Brazelton test

## Introduction

Evidence on the functional effects of vitamin B-6 deficiency of infants has existed since the 1950s when irritability, aggravated startle responses, and convulsive seizures were first observed in infants who were inadvertently fed a formula deficient in vitamin B-6 (1). These signs were noted for ~300 infants among the thousands who were fed the improperly processed formula. Adults have also shown negative behavioral changes in response to extremely low intakes of vitamin B-6. The symptoms differ, however, from those observed in infants. In a now classic study (2) of an adult male fed a vitamin B-6–free diet for 2 mo, depression and mental confusion resulted, which disappeared after supplementation with pyridoxine hydrochloride (PN-HCl). A similar observation was made by Sauberlich et al (3) who noted irritability, depression, and loss of a sense of responsibility in a group of male subjects who were fed a diet essentially free of vitamin B-6 for 3 wk, followed by low concentrations of the vitamin for 11 wk. Although the issue remains controversial, depression was also reported in some women as a side effect of estrogen-containing oral contraceptives (4–6). In a double-blind, crossover study (6), women with an absolute deficiency of vitamin B-6 were relieved of their depression by taking daily supplements containing 40 mg PN-HCl.

The above evidence suggests that a vitamin B-6 deficit may influence infant development in one of three ways: *1*) directly, through its influence on infants' central nervous development; *2*) indirectly, through its influence on caregiver infant relations, which in turn influence developmental outcomes; and *3*) through a combination of both direct and indirect influences. A fuller understanding of the process whereby vitamin B-6 status translates into development differences would require concurrent measurement of vitamin B-6 influences on both caregiver and infant behaviors. To our knowledge such a study has not yet been reported. The present paper presents data on this question.

The present study was adjunct to a large US Agency for International Development (USAID) study conducted in a semirural Egyptian village near Cairo in which, among numerous variables investigated, the nutrient quality of breast milk was examined. Extensive research by Karra et al (7) showed that milk of the Egyptian village women was not significantly different in calcium, magnesium, or zinc concentrations from that of healthy American counterparts. Among several nutrients that were examined, including folate and vitamin C concentrations, vitamin B-6 was the only nutrient that appeared to be present at a concentration suboptimal for adequate infant nutrition. In a pilot study, 9 of 22 milk samples obtained at random from the village women were found to contain low concentrations of vitamin B-6. A follow-up investigation made 5 mo after the initial study showed that four of the women continued to have low concentrations (< 500 nmol/L) of vitamin

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[2] Paper #11895 of the Purdue University Agricultural Experiment Station, West Lafayette, IN.

[3] Supported in part by Thrasher Research Fund Grant 2798-2 and USAID Research Support Grant DAN-1309-G-SS-1070-00.

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B-6 in their milk. One of the four infants examined exhibited poor neurological tone and the inability to sit alone at age 9 mo. On the basis of these preliminary findings, this study was designed to assess vitamin B-6 adequacy among mothers and breast-fed infants in the Egyptian village and possible functional consequences of vitamin B-6 inadequacy on pregnancy outcome, neonatal behavior, and mother-infant interactions.

## Methods

### *Subjects*

Sixty-nine pregnant Egyptian women from the semirural village of Kalama, 25 km from Cairo, volunteered to participate in this study commencing at the time of delivery. At this same time the mothers and their infants were also participants in the large USAID project (8) carried out in the village during 1982–1987.

All procedures used in this study were approved by the University Committee on the Use of Human Research Subjects. Informed consent forms were records of verbal consent recorded by field workers because most mothers were illiterate. Attrition of subjects who had been participants in the USAID project since early pregnancy occurred during the course of this 6-mo study after delivery. Also, the number of mothers and infants who participated in different phases of the study varied.

### *Breast milk collection and vitamin B-6 analysis*

A team of trained Egyptian field workers from the Nutrition Institute in Cairo collected samples of breast milk from participating village mothers monthly throughout the first 6 mo of lactation. During home visits between 1000 and 1200, samples of milk were collected by the mother at the beginning of a feeding after milk letdown. Samples were expressed either manually or by use of a breast pump and were collected into plastic amber vials that had snap caps. Previous work indicated that neither the time of milk collection during a feed nor the time of day significantly influenced the vitamin B-6 concentration in human milk (9). After collection, milk samples were placed immediately in ice chests and were transported within 3-h from the village to the Nutrition Institute in Cairo where they were stored at −20 °C. Subsequently the vials were packed in dry ice and transported by air shipment to the nutrition laboratory at Purdue University, where they were stored again at −20 °C until analysis. Total vitamin B-6 content was determined by the *Saccharomyces uvarum* microbiological assay based on procedures described previously by Storvick et al (10), Thiele and Brin (11), and Toepfer and Polansky (12).

### *Infant-weight measurements*

The team of Egyptian field workers who collected the milk samples were also trained and supervised in infant-weighing procedures. The team was responsible for measuring and recording weights of the infants at birth and monthly through age 6 mo. A portable, battery-operated electronic scale (model DS-1, K-Tron, Inc, Scottsdale, AZ) was transported by field workers to the village homes where measurements were made. This balance is accurate to 1 g and is particularly suitable for field work because it does not require leveling and several measurements are averaged automatically over 3 s, thus stabilizing the readings from a moving infant. The digital display was visible even in poor light, commonly found in village homes.

### *Brazelton Neonatal Behavioral Assessment Scale*

The Brazelton Neonatal Assessment Scale (BNAS), Kansas Supplement, was administered by an Egyptian child psychiatrist who was trained to the point of criterion reliability at the University of Kansas. Criterion reliability was achieved when the trainee's score was not more than one point different from the trainer's score for 90% of the items. The BNAS is an instrument designed to test the infant's neurologic intactness, alertness, and social interaction. The BNAS consists of 20 neurological items and 27 behavioral items. Currently the BNAS is among the most widely used instruments for assessing neonatal status. Details on the reliability and validity of the BNAS can be found in the most recent version of the manual (13). The tests were administered to 70% of the infants by day 5 after birth and were completed for all infants by day 7. The curvilinear behavioral items of the BNAS were rescored according to the method described by Lester (14) so that the highest score indicated the most favorable performance; the BNAS items were also clustered according to the procedure described by Lester (14).

### *Caregiver-infant interaction*

Starting when infants were age 3 mo and continuing through age 6 mo, infants and their caregivers were observed in their village homes twice monthly during 30-min observation periods. Mothers were the primary caregivers for 63% of the observations. Observations were carried out by a group of Egyptian field workers who were specially trained in observational techniques. Observation procedures and the codes that were utilized had been previously validated with a sample from the same village. Ten observation codes encompassing a variety of developmentally relevant maternal behaviors were coded (Table 1). Observation codes were chosen on the basis of previous research (15), indicating the relevance for infant development of caregiver behaviors assessed by those codes. Because of personnel problems encountered during the study we were unable to obtain formal test-based measures of infant development at 6 mo. However, we were able to derive two measures of infant behavior from our direct observations, namely amount of infant distress and number of spontaneous infant vocalizations between ages 3 and 6 mo. Interobserver agreement on both caregiver and infant behaviors obtained during the course of the study was found to be satisfactory ($\bar{x}$ 0.93; range 0.58–1.00).

### *Statistical analysis*

Statistical analyses of the data were performed on an IBM 3083 computer (IBM, Armonk, NY) with the technical assistance of consultants from the Department of Statistics at Purdue University. *SAS* computer programs (16) for statistical analysis were the primary tools used in the analyses. The *Statistical Package for the Social Sciences, SPSS-X* (17), was also utilized for factor analysis and reliability testing of the Brazelton clusters. Both simple and multiple regressions were used in data analysis: multiple regression was used as a model building tool and in the process, many different models were examined. Essentially all subsets of variables were examined as candidate predictors and lists of subsets, ordered by $R^2$, were generated

TABLE 1
Description of observational codes for caregiver-child interactions

| Code name | Code description |
|---|---|
| Number of people in home | Number of people within five feet of the child |
| Responsible caretaker | Person who has responsibility for the child |
| Mother caregiver within reach of the child | Number of times the mother or caregiver can reach over and touch the child |
| Physical contact—amount | Number of times the child is picked up, held, or carried |
| Duration of contact | Amount of time the child is picked up, held, or carried |
| Carrying while doing other activities | Amount of time the child is held or carried while the carrier is doing activities not involving the child |
| Number of spontaneous vocalizations | Number of times adult or sibs spontaneously vocalized to the child |
| Verbal responsivity | Nature of the response to child vocalization: 1, no response; 2, nonverbal response (ie, touching the child), and 3, verbal response |
| Effectiveness of response | Whether the caregiver's intervention was effective in soothing the child's distress |
| No response to distress | Number of times no one responded to the child's distress |

within the subset size by use of the statistical software package, *SAS Procedure RSQUARE*. The CP criterion (18) was used to select subset models. When predictor variables were correlated, it was often the case that several different subsets of variables gave essentially the same predictive power. The methods allowed attention to be focused on those models that had the greatest potential for answering the research questions. The model for birth weight as it related to maternal vitamin B-6 status was a linear spline model with one fitted knot (at 410 nmol vitamin B-6/L milk). The model was analyzed by use of a nonlinear-regression procedure (*SAS PROC NLIN*) based on asymptotic theory for nonlinear models.

Several variables in addition to maternal vitamin B-6 status were also analyzed statistically as possible correlates of neonatal behavior. These included household socioeconomic status (SES); parity; maternal age; maternal body mass index; body weight in early and late pregnancy; weight gain in the last two trimesters of pregnancy; maternal animal and plant protein intake and energy intake in the last two trimesters of pregnancy; maternal iron status as measured by ferritin, hematocrit, or hemoglobin in the second and third trimesters; gestational age of the infant; and birth weight and length, both expressed as percent of the median of the National Center for Health Statistics (NCHS) standards (19). When BNAS items and a variable listed above correlated significantly with maternal vitamin B-6 status, BNAS items were included in a multiple-regression analysis as the independent variable with both maternal vitamin B-6 status and other correlates entered as dependent variables.

## Results

Confirming results obtained in the pilot study, the average concentration of vitamin B-6 in milk of the Egyptian women was very low compared with typical values of unsupplemented and supplemented Western women (**Fig 1**). Low values for individuals suggested poor vitamin B-6 status among more than one-third of the Egyptian women examined. The physiological consequences of this were evidenced by the significant positive relationship of vitamin B-6 concentrations in milk (< 410 nmol/L) and birth weight (**Fig 2**). On the other hand, the relationship was not statistically significant for higher concentrations of vitamin B-6 (> 410 nmol/L). For 27 women who had concentrations of vitamin B-6 < 430 nmol/L milk, this index, a proxy for poor maternal vitamin B-6 status, increased the power to predict birth weight when used in conjunction with other predictors of birth weight including maternal early pregnancy weight and weight gain during the last two trimesters of pregnancy (**Table 2**).

Relationships between birth weight and the combined effects of collections of variables were investigated by use of multiple-regression techniques in model building. The 14 variables that were considered as candidate predictors for birth weight are shown in **Table 3**. The method used in model building was based on an examination of all possible subsets as predictors by use of *SAS Procedure RSQUARE* and the CP criterion to select subset models (16). The CP criterion pointed to only one candidate model as the best predictor of birth weight. This model included early pregnancy weight and weight gain during pregnancy with an $R^2$ of 0.44. When the model included any of the other variables, except maternal vitamin B-6 status, $R^2$ was changed only slightly. The inclusion of maternal vitamin B-6 status in the model improved the $R^2$ to 0.58. Of the variables examined, clearly body weight in early pregnancy, weight gain during 3–9 mo of pregnancy, and maternal vitamin B-6 status were significant predictors of birth weight (Table 2).

BNAS items assessing consolability, rapidity of build-up to the crying state, and the number of responses to aversive stimuli (irritability) were significantly related to maternal vitamin B-6 status (**Table 4**). Consolability measures the number of maneuvers the examiner must make to bring a crying infant to a quiet state. A high score indicates an infant who quiets simply

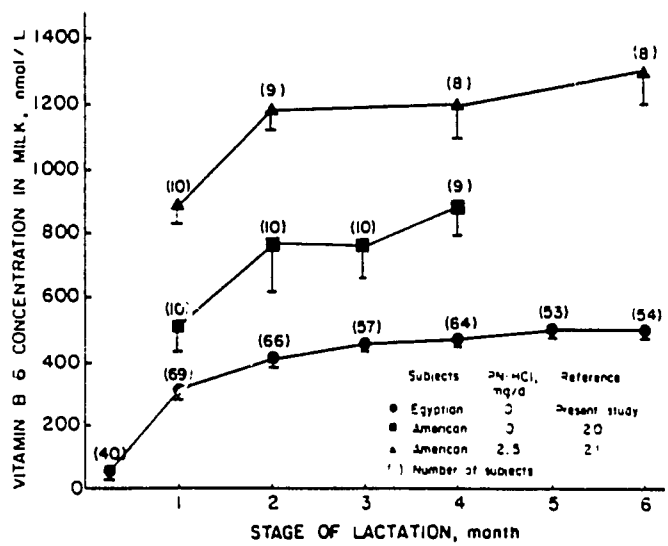


FIG 1. Vitamin B-6 concentrations in milk of unsupplemented Egyptian women compared with values reported for unsupplemented and supplemented American women at different stages of lactation.

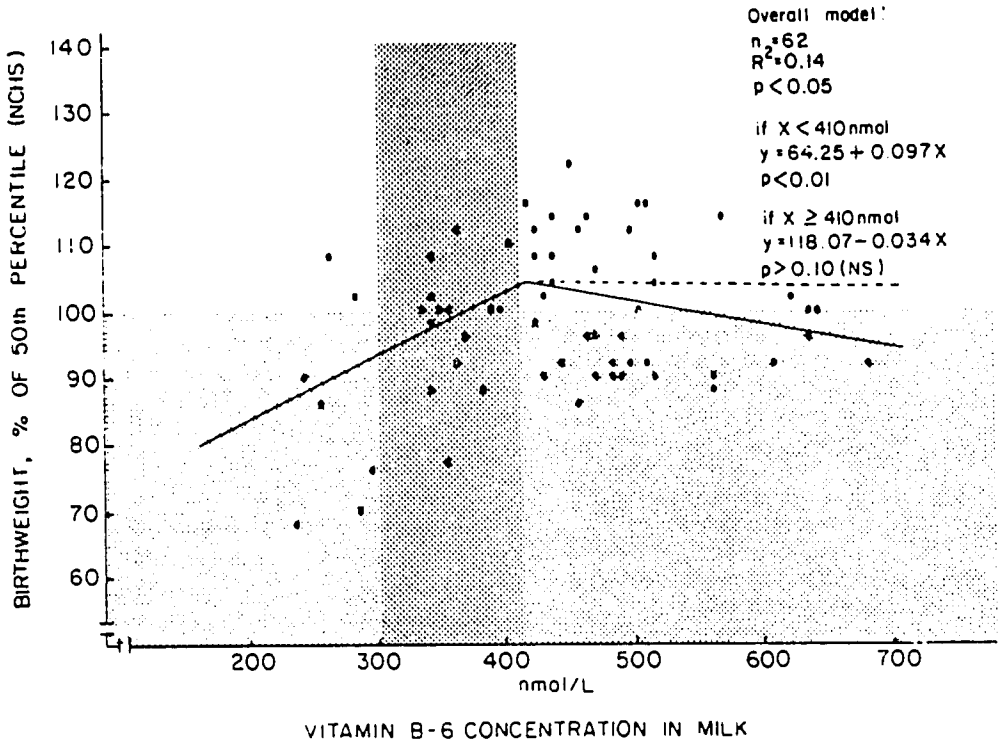


FIG 2. Relationship of birth weight of Egyptian infants expressed as percent of the 50th percentile National Center for Health Statistics (NCHS) to vitamin B-6 concentration in breast milk, a proxy for maternal vitamin B-6 status. The equations for the model are represented by the solid line: the dashed line indicates that the slope of X > 410 nmol is not significantly different from 0. Light shaded area includes birth weight values < 50th percentile (NCHS reference). Dark shaded bar represents the range of vitamin B-6 concentrations in human milk, which have been associated with clinical signs of vitamin B-6 deficiency in some breast-fed infants (1).

in response to the examiner's face or to the face and voice alone, whereas a low score is given to an inconsolable infant. Rapidity of build-up assesses the period of time during which an infant can maintain control as increasingly aversive stimuli are administered. A high score indicates that an infant moves from a quiet to a crying state in the middle or end of the exam, not at the beginning. The number of responses to aversive stimuli measures the number of times the infant becomes irritable to specific stimuli during the course of the exam. This item is presented as the actual number of responses and not as a rescored item. Results indicated that adequate maternal vitamin B-6 status was associated with easier consolability of the infant ($r = 0.39$, $p < 0.01$), and with longer rapidity of build-up before distress of the infant ($r = 0.37$, $p < 0.05$). Adequate maternal vitamin B-6 status was also associated with more irritable responses of the infant when aversive stimuli were presented during the BNAS examination ($r = 0.49$, $p < 0.01$). Maternal vitamin B-6 status was a more powerful predictor of neonatal behavior than were all other dependent variables.

TABLE 2
Multiple-regression models for predicting birth weight (the dependent variable), expressed as percent of the median of National Center for Health Statistics (NCHS)

| Independent variables | Regression coefficient | SEM | $p$ | $R^2$ |
|---|---|---|---|---|
| Model 1 ($n$ = 27) | | | | |
| Early pregnancy weight | 0.63 | 0.16 | 0.0006 | 0.44 |
| Weight gain during pregnancy | 1.40 | 0.58 | 0.03 | |
| Intercept | 52.6 | 11.3 | | |
| Model 2 ($n$ = 27) | | | | |
| Maternal vitamin B-6 status* | 0.07 | 0.03 | 0.02 | 0.58 |
| Early pregnancy weight | 0.51 | 0.15 | 0.003 | |
| Weight gain during pregnancy | 1.14 | 0.54 | 0.05 | |
| Intercept | 35.9 | 12.2 | | |

* Vitamin B-6 concentration of milk, < 475 nmol/L milk.

TABLE 3
Maternal and household variables considered as candidate predictors for birth weight

| |
|---|
| Characteristics of the mother |
| Age |
| Education (y) |
| Parity |
| Number of fetal deaths |
| Height |
| Weight at 3 mo pregnancy |
| Weight gain, 3–9 mo pregnancy |
| Average energy, animal and plant protein intakes across second and third trimesters of pregnancy |
| Vitamin B-6 status |
| Percentage of time sick, |
| Excluding skin ailments |
| With skin ailments |
| Characteristics of the household |
| Socioeconomic status |
| Sanitation-hygiene index |
| Infant and child mortality |

TABLE 4
Relationship between vitamin B-6 concentration of breast milk and behavior of the neonate*

| Independent variable | Dependent variable† | Regression coefficient | SEM | $p$ | $R^2$ |
|---|---|---|---|---|---|
| Vitamin B-6 concentration of milk (nmol/L) | Consolability ($n$ = 44) | 0.004 | 0.001 | 0.009 | 0.15 |
| | Intercept | 4.03 | 0.62 | | |
| | Rapidity of build-up to crying state ($n$ = 44) | 0.004 | 0.002 | 0.01 | 0.14 |
| | Intercept | 2.08 | 0.69 | | |
| | Response to aversive stimuli ($n$ = 44) | 0.004 | 0.001 | 0.001 | 0.23 |
| | Intercept | 2.65 | 0.53 | | |

* $n$ = 44.
† Brazelton Neonatal Behavior Assessment Scale.

Initial investigation showed that maternal vitamin B-6 status was not correlated with any of the seven BNAS items that had been clustered. However, a reliability check of the clusters when the scores of 90 Egyptian infants were used, indicated that only three clusters (reflex, habituation, and orientation) had satisfactory internal consistency. Consequently, analysis with cluster scores was no pursued.

The caregiver-infant interaction (CII) data of infants aged 3–6 mo were statistically treated in the same ways as the BNAS items. That is, the CII variables were analyzed in relation to maternal vitamin B-6 status (Table 5) and to the indices of maternal anthropometry, maternal food intake, iron status (assessed during lactation), maternal age, parity, and SES. Those CII items that correlated significantly with maternal vitamin B-6 status and another variable were analyzed in a multiple-regression model. These analyses indicated that only maternal vitamin B-6 status was significantly important in predicting CIIs. Correlations between maternal vitamin B-6 status, averaged over the first 6 mo of age, and observation codes aggregated over 3 mo of observation indicated that poor maternal vitamin B-6 status was associated with higher levels of nonresponse to infant vocalization ($r = -0.43$, $p < 0.05$), less effective response to infant distress ($r = -0.39$, $p < 0.05$), and greater utilization of sibling caregivers ($r = -0.45$, $p < 0.05$).

In terms of infant behavior, the amount of infant distress at age 3–6 mo was unrelated to vitamin B-6 status. However, both maternal vitamin B-6 status and infant weight at age 6 mo (expressed as percent of the NCHS median) added unique variance to the prediction of number of infant vocalizations (Table 6). At age 6 mo the average weight of 38 normal birth weight (NBW) male infants in the study was between the 10th and 25th percentiles of the NCHS standard and the average weight of 29 NBW female infants in the study was between the 25th and 50th percentiles. Before age 6 mo, none of the infants received food supplements to breast milk that were substantial sources of nutrients. However, small amounts of sugar water, sugary concoctions, and rice water were fed routinely to most infants from birth (8).

## Discussion

Because of cultural constraints in the Egyptian village, blood collection was not possible from most of the subjects. Of central importance to this study is the use of vitamin B-6 concentration in breast milk as a predictor of maternal vitamin B-6 status, a relationship confirmed by previous research. Findings from a study in humans (20) showed a significant relationship between vitamin B-6 concentration in milk measured by high-performance liquid chromatography and two indices commonly used in vitamin B-6 nutrition assessment, erythrocyte alanine aminotransferase activity ($r = 0.61$) and plasma pyridoxal phosphate (PLP) concentrations ($r = 0.74$). These findings were supported by subsequent work from this laboratory (SJ Chang and A Kirskey, unpublished observations, 1985), which also showed that plasma PLP concentrations of mothers

TABLE 5
Relationship between vitamin B-6 concentration of milk and caregiver-infant interactions at ages 3–6 mo

| Independent variable | Dependent variable | Regression coefficient | SEM | $p$ | $R^2$ |
|---|---|---|---|---|---|
| Vitamin B-6 concentration of milk (nmol/L) | No response to child's vocalization ($n$ = 24) | −0.0016 | 0.0007 | 0.03 | 0.20 |
| | Intercept | 1.15 | 0.32 | | |
| | Noneffective response to infant's distress ($n$ = 24) | −0.0009 | 0.21 | 0.05 | 0.18 |
| | Intercept | 0.98 | 0.21 | | |
| | Percent of time older sibling is caregiver ($n$ = 29) | −0.0007 | 0.0003 | 0.01 | 0.20 |
| | Intercept | 0.42 | 0.12 | | |

TABLE 6
Multiple-regression model for predicting infant vocalizations at ages 3–6 mo*

| Dependent variable | Independent variable | Regression coefficient | SEM | $p$ | $R^2$ |
|---|---|---|---|---|---|
| Number of infant vocalizations | Vitamin B-6 concentration of milk (nmol/L) | 0.004 | 0.002 | 0.04 | 0.30 |
| | Infant weight at age 6 mo (% of NCHS median) | 0.036 | 0.002 | 0.04 | |
| | Intercept | 0.30 | 1.63 | | |

* $n = 25$.

were positively and significantly correlated ($r = 0.71$, $p < 0.01$) with those of their breast-fed infants at age 6 mo. Other work from this laboratory showed that the concentrations of vitamin B-6 in human milk closely and significantly paralleled the mother's intake of vitamin B-6 (21, 22) and that when maternal vitamin B-6 status was marginal and intake of the vitamin was low, only a small percentage of the intake appeared in milk (23). In agreement with these findings, experiments in rats (24, 25) showed that when vitamin B-6 deficiency was imposed during lactation, liver and muscle tissues failed to release significant amounts of vitamin B-6 into milk.

In view of these findings and the objections of villagers to blood sampling, this study used vitamin B-6 concentrations in milk, collected monthly from 1 to 6 mo of lactation, as a proxy for maternal vitamin B-6 status. Vitamin B-6 concentrations of milk were averaged over time to smooth for intraindividual variability. Maternal food intake during lactation closely resembled that during pregnancy because of the limited variety of foods included in the diets of villagers and the constancy of their food intakes over time (8). Maternal diets averaged ~2000 kcal/d and 67 g protein/d during the last two trimesters of pregnancy and 2125 kcal/d and 74 g protein/d during the first 6 mo of lactation (8). During pregnancy, diets were not significantly different from those of nonpregnant women. On the basis of cultural beliefs, some special foods (eg, chicken) were added during lactation and this was reflected in small increases in energy and protein intakes during lactation as compared with pregnancy. The vitamin B-6 content (mg/d) of typical 24-h food intake composites, analyzed in the parent project (8) for three women of differing physiological states was 0.75 for a pregnant woman, 0.96 for a lactating woman, and 0.89 for a pregnant and lactating mother.

In this population of Egyptian women, suboptimal vitamin B-6 status was apparent in more than one-third of those studied. The average vitamin B-6 concentration in the milk of 70 women was 435 nmol/L, considerably lower than that typically reported for women in Western societies. The ratio (expressed as μg/g) of vitamin B-6 to protein was 0.29 for colostrum and 5.77 for mature milk averaged over 1–6 mo of lactation. These ratios were substantially lower than the ratio of 15 [Recommended Dietary Allowance (RDA)] (26).

Classic work on human milk composition by Macy et al (27) showed vitamin B-6 concentrations of 655 nmol/L, the same value as that reported by the USDA (28) 26 y later for 88 subjects. Ford et al (29) reported a vitamin B-6 concentration of 635 nmol/L milk for mothers of term infants. Although other investigators reported a range of values (21, 30, 31), an opinion in the field is that a concentration of vitamin B-6 of ≥ 600 nmol/L milk is needed for normal growth and development of human infants. Approximately 40% of the Egyptian mothers had vitamin B-6 concentrations in their milk of < 415 nmol/L when monthly values were averaged from 1 to 6 mo lactation. At these lower concentrations of vitamin B-6 in milk, reflecting less than optimal maternal vitamin B-6 status, birth weight was significantly influenced. The ratio of maternal vitamin B-6 status to vitamin B-6 concentration in milk was strong enough to predict birth weight by itself (Fig 2) as well as in conjunction with other powerful predictors of birth weight such as early pregnancy weight and maternal weight gain during pregnancy (Table 2).

The medical records of one male infant indicated that the infant experienced a convulsive seizure in the first month after birth. The mother of this infant was not included in the present study because only one milk sample was collected from her and that was at 4 wk postpartum. At this time the mother's vitamin B-6 status appeared extremely poor, reflecting a vitamin B-6 concentration in milk of only 225 nmol/L. Bessey et al (32) and later Kirksey and Roepke (33) observed convulsive seizures in breast-fed infants whose mother's milk was low in vitamin B-6 (< 400 nmol/L). It cannot be substantiated that the convulsive seizure noted in the Egyptian infant was secondary to vitamin B-6 deficiency but the case provides circumstantial evidence to the existing picture of poor maternal vitamin B-6 status, which possibly resulted in adverse physiological consequences to the breast-fed infant.

Maternal vitamin B-6 status significantly influenced neonatal behavior, as evidenced by the infants of mothers assessed as adequate in vitamin B-6 being more consolable, building-up to a crying state at a more appropriate tempo, and responding to more aversive stimuli than infants of mothers assessed as poor in vitamin B-6 status. Consolability and rapidity of build-up to crying were items that fit particularly well with the hypothesized behavioral changes of an infant deficient in vitamin B-6, ie, one who requires more intervention to quiet from a crying state and is more easily upset. The positive relation between vitamin B-6 status and number of responses to aversive stimulation, while seemingly inconsistent with this interpretation, may reflect differences in scoring criteria for the irritability and rapidity items. Rapidity of build-up reflects the point in the exam at which the neonate shows intense distress, ie, crying for > 15 s. In contrast, irritability can be scored when the neonate exhibits little (3 s) fussing. Integrating across these differing criteria suggests that neonates who are not deficient in vitamin B-6, while more responsive to aversive stimuli, are also more easily consoled and are thus less likely to show full blown distress when there is increasing aversive stimulation. Neonates who

are deficient in vitamin B-6, while showing less fussing, are more prone to exhibit intense distress earlier in the exam and are less easily consoled by adult interventions.

Multiple-regression analysis of the BNAS items related to maternal vitamin B-6 status showed that, in each case, maternal vitamin B-6 status was a much stronger predictor than were other correlates of birth weight (ie, gestational age or household SES) in predicting infant behavior. Even though infants of families of the lowest SES were more easily irritated than were those from the more economically privileged families, maternal vitamin B-6 status was stronger statistically than was SES in predicting infant BNAS performance by multiple-regression analysis. These results offer supportive evidence that maternal vitamin B-6 status was the strongest factor, of the many factors examined, that influenced the infants' behavior with respect to consolability, rapidity of build-up to a crying state, and response to aversive stimuli. When vitamin B-6 status of the mother was entered into the multiple regression with any of the neonatal outcome variables, maternal vitamin B-6 status was either the only significant factor affecting neonatal behavior or neither factor was significantly related.

Although infant distress after the neonatal period was unrelated to vitamin B-6 status, the amount of spontaneous infant vocalization was significantly correlated with maternal vitamin B-6 status as reflected by the vitamin B-6 concentration in breast milk. The lack of relation of vitamin B-6 status to infant distress as compared with infant vocalizations may reflect the substantially lower interobserver reliability for distress ($r = 0.66$) as compared with vocalizations ($r = 0.98$). The fact that neonatal build-up to distress measured by the BNAS during the first week of life was related to vitamin B-6 concentration, whereas infant distress measured at age 3–6 mo was unrelated, can be seen either as caused by lower interobserver reliability for scoring infant distress or as a function of differences in the testing conditions. The BNAS was administered by a member of the project team; the interaction between the mother and infant was held to a minimum during the testing. In contrast, during the field observations of infants from ages 3–6 mo, there were no restraints on the mothers' reactions to infant distress. As such, these two distress measures were not comparable.

The number of vocalizations was also highly correlated with infant weight at age 6 mo. When both factors, maternal vitamin B-6 status and infant weight at age 6 mo, were entered into a multiple-regression analysis, both were important in predicting the number of vocalizations of the infant.

Observations of CIIs from 3 to 6 mo after birth showed that maternal behavior was also influenced by vitamin B-6 status. Mothers assessed with lower vitamin B-6 status showed a greater percentage of nonresponses to their infants' vocalizations and fewer effective responses to their infants' distress episodes than did mothers assessed as having better vitamin B-6 status. Mothers with poor vitamin B-6 status were also more likely to use an older sibling as caregiver.

The findings of this research are believed to represent the first demonstration of a relation between vitamin B-6 status of lactating mothers and certain aspects of their behavior toward their infants. Given the small sample size and the unique nature of the population, replication attempts clearly are essential. Assuming that the present findings can be replicated, a critical question involves the nature of the link between vitamin B-6 status and maternal behavior. One potential link involves the similarity between the behavior of Egyptian mothers assessed as having inadequate vitamin B-6 nutriture and the behavior of depressed North American mothers toward their infants (34, 35). Vitamin B-6 is a critical coenzyme related to the production of certain neurotransmitters such as serotonin (36, 37), which have been implicated in mood disorders (38). Some studies reported a relation between vitamin B-6 concentration and clinical depression (39, 40). Studies of women receiving high-dose estrogen preparations reported depression in only ~6% of women examined (5); this depression was responsive to PN-HCl if the women were extremely depleted of vitamin B-6 (6, 41). Although it seems unlikely that most of the women with low vitamin B-6 status in this study suffered from clinical depression, the relation of maternal vitamin B-6 status to both maternal mood and behavior toward their infants merits further inquiry.

The present pattern of results, indicating that vitamin B-6 deficits concurrently influence both infant behavior and developmentally relevant caregiver interaction patterns, tentatively suggest that the developmental consequences of low vitamin B-6 concentrations may be best viewed in terms of a combination of both direct and indirect influences. To fully illustrate the process whereby vitamin B-6 deficiency is translated into behavioral deficits, long-term follow-up of vitamin B-6–deficient infants and their caregivers seems essential. Future follow-up studies should include a more direct assessment of maternal mood, blood indices of vitamin B-6 status, different measures of caregiver interaction patterns as the infant grows older, more direct measures of infant cognitive and noncognitive development (ie, memory, discrimination abilities, exploration patterns, activity level), and double-blind administration of PN-HCl supplement and placebo.

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# APPENDIX B

## CATEGORY OF FOODS

| | |
|---|---|
| CATEGORY -1: | BEVERAGE NONCARBONATED |
| | Tea, Coffee, Anisea, Cacao, Caraway, Carcadeh leaf, Cinnamon, Fenugreek, Ginger, Tamarind, Toulu |
| CATEGORY -2: | BEVERAGE SOFT DRINKS |
| | Soft drinks, Gingerale, Syrup, Lemon lime soda |
| CATEGORY -3: | ORS |
| | Rahedian |
| CATEGORY -4: | CEREALS - RICE |
| CATEGORY -5: | CEREALS - WHOLE GRAINS |
| | Barley, Burghul (whole or ground), Popcorn, Semolina, Sorghum, White maize, Yellow maize, Beleehah |
| CATEGORY -6: | CEREALS MACARONI |
| | Macaroni, Cheese noodles |
| CATEGORY -7: | CEREALS RURAL BREAD |
| | Baladi bread (Egyptian, 85% ext), Rural bread (wheat:corn 1:1), Rural bread (2:1, 3:1, 3:2, 4:1, 7:1, 1:2) |
| CATEGORY -8: | CEREALS BREAD |
| | Corn flour (96% ext), French bread,Crispy French bread or bread crums, Karate, Wheat flour (85% ext, 70% ext), White bread (arabic, 70% ext), Buns, Mafrouka, French bread-sesame seed, Collagepapu |
| CATEGORY -9: | STARCH BASED PUDDING |
| | Corn starch, Rice starch |
| CATEGORY -10: | PASTRY WITH GHEE |
| | Fatir Meshatet, Fetir, Lokmadis |
| CATEGORY -11: | EGGS AND EGGS PRODUCTS |
| | Hen, Duck, Egg white, Egg yolk, Egg cooked |

CATEGORY -12: OIL/FAT ANIMAL SOURCES

Mixed animal & hydrogenated vegetables oil, Butter (Buffalo/cow), Cream, Tallow (Lamb fat), Beef fat, Ghee, Goat fat, Chicken fat, Mocta

CATEGORY -13: OIL/FAT PLANT SOURCES

Vegetables oil, Sesame oil, Corn oil, Cotton seed oil, Olive oil

CATEGORY -14: FISH ALL VARIETIES

CATEGORY -15: FRUITS REGULAR

Guava, Date (black, red, yellow), Watermelon, Banana, Mango, Melon, Prickly pear, Apple, Cherry, Harankash, Mixed fruit, Peach, Pear, Plum, Pomegranate, Raspberry, Strawberry, Apricot, Figs, Prunes, Grapes,

CATEGORY -16: FRUITS CITRUS

Lime, Mandarin, Orange, Lemon (sweet), Grapefruit, Pineapple

CATEGORY -17: FRUIT JUICES

Apricot, Banana, Lime, Mango, Orange, Pineapple, Sugar cane, Guava,

CATEGORY -18: LEGUME BROAD BEAN

Broad bean

CATEGORY -19: LEGUME OTHERS

Lentil (peeled), Lentil(whole), chick pea, Cow pea, Dry pea, Kidney bean, Lupine, Sesame seed, Chicken pea white

CATEGORY -20: LEGUME PRODUCTS

Taamia, Tahina

CATEGORY-21: MEAT ANIMAL ORIGIN

Beef, Camel, Goat, Lamb, Rabbit, Veal

CATEGORY -22: MEAT AND MEAT PRODUCTS

Brains, Head meat, Heart, Joint, Kidney, Liver, Lung, Pancreas, Spleen, Stomach, Tongue, Intestine, Meat cube, Beef boullion, Chicken, Duck, Pigeon, Goose, Poultry liver, Chicken broth, Duck broth, Cube of poultry soup, Goose broth, All kinds of broth

CATEGORY -23: HUMAN MILK

Breast milk

CATEGORY -24: MILK

Buffalo, Cow's milk (full, half cream, condensed, skimmed), Goat's milk, Sahlal

CATEGORY -25: MILK PRODUCTS

Skimmed cheese, White cheese - half cream, White cheese - full cream, Cheese with mish, Ice cream (varieties), Mish - from whole milk, Mish - from skim milk, Processed cheese, Yogurt, Ricotta cheese

CATEGORY -26: NUTS

Peanut, Almond, Walnut

CATEGORY -27: SEASONING

Salt

CATEGORY -28: CONDIMENTS

Black pepper, Ketchup, Cumin seeds

CATEGORY -29: SWEETS

Sugar

CATEGORY -30: SWEETS AND SWEETS PRODUCTS

Halawa tehinia, Molasses, Assorted ready-made biscuits, Candy, Chocolate, Honey, Jam, Molasses stick, Mouled sweets (chick pea, malban, peanut, sesame), Toffee, Beseasa, Basbousa, Ashoura, Feast biscuit, Konaffa, Mishabek, Sugar cookie

CATEGORY -31: TUBERS

White potato, Colacacia, Sweet potato

CATEGORY -32: POTATOES

White potato

CATEGORY -33: VEGETABLES EGGPLANT

Eggplant (black, Greek, black, white)

CATEGORY -34: VEGETABLES RAW/SALAD

Cucumber, Lettuce, Parsley, Celery, Radish (red), Garden Rocket, Watercress

CATEGORY -35: VEGETABLES TOMATO

Tomato

CATEGORY -36: VEGETABLES ONIONS

Onion, Onion (green), Garlic, Green pepper (sweet), Leek, Mint

CATEGORY -37: VEGETABLES ORANGE/YELLOW

Sweet potato, Carrot (orange, red), Pumpkin, Yellow potato

CATEGORY -38: VEGETABLES OLIVE

Olive (black, green)

CATEGORY -39: VEGETABLES ALL OTHER TYPES

Purslane, Artichoke, Beet root, Cabbage, Chard, Chickpea (green), Chicory, Coriander (green), Grape leaves, Green bean, Radish (white), Red pepper (hot), Spinach, Turnip

CATEGORY -40: VEGETABLES EXCEPT SALAD AND OLIVES

Chard, Chickpea (green), Chicory, Coriander (green), Fenugreek (green),Grape leaves, Green bean, Leek, Mallow, Mint, Radish (white), Red pepper (hot), Spinach, Turnip, Green pepper, Artichoke, Beet root, Cabbage, Eggplant (black-Creek, black, white), garlic, Jew's mallow, Okra, Onion, Onion (green), Runner bean, Squash, Tomato, Broad bean

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APPENDIX C

# Relationship between nutrition and development in Kenyan toddlers

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**The relationship between mild to moderate malnutrition, as measured by food intake and anthropometric status, and developmental outcome was explored in 110 Kenyan toddlers. Developmental outcome was assessed at 30 months of age by the Bayley Mental and Motor scales and by evaluation of play behaviors. Verbalization and play during months 15 to 30 were also evaluated. Family background and home rearing conditions were assessed, and these variables were separated from the correlations between nutrition and outcome by partial correlation methods. Food intake was related to anthropometric status, play behaviors, and total amount of verbalization and play even when the potentially confounding effects of certain family background and home rearing variables were covaried. Food intake was not related to Bayley Mental and Motor scores, but measures of length and weight were, even when family background and home rearing variables were held constant. Mild to moderate malnutrition does appear to affect the child's development adversely even when other environmental characteristics, which also relate to development, are considered. (J PEDIATR 1989;115:357-64)**

Severe protein-energy malnutrition during the early years of life is associated with retarded physical and mental development and behavioral disturbances that persist into adult life.[1-3] Furthermore, severe malnutrition has a detrimental effect on the child's development beyond the effects of the social and cultural deprivation that typically accompany it.[2,4-8]

The effects of mild to moderate malnutrition on the development of children are less clear. Some studies show no difference in cognitive scores of malnourished and better-fed siblings[9] and no effect of nutritional status on cognitive measures after control of variables for socioeconomic status.[10] However, other studies show lower IQ scores among more malnourished individuals within SES quartile groups[11] and significant relationships between nutritional indexes and cognitive, motor, and behavioral outcomes even after the effects of SES were covaried or held constant by partial correlation methods.[12-14]

It is difficult to differentiate the independent effect of mild to moderate malnutrition from the covarying effects of environmental factors in any single study. First, in our study, nutrition was measured by both direct observation and weighing of food intake and anthropometric status; most studies have used only anthropometric status to reflect nutritional status. Second, we considered the confounding effects of SES and also the effects of other possible confounders, such as parental IQ and literacy and care-giver interactions. Care-giver interactions may be especially

| | |
|---|---|
| IQ | Intelligence quotient |
| SES | Socioeconomic status |

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**Table I.** Mean nutritional indexes for male and female toddlers

| | z Scores* | |
|---|---|---|
| | Girls (n = 57) | Boys (n = 53) |
| Physical measures | | |
| Length at 30 mo | −1.92 ± 0.9 | −1.85 ± 1.1 |
| Weight at 30 mo | −1.52 ± 1.0 | −1.43 ± 0.8 |
| Weight/length ratio | −0.40 ± 0.8 | −0.37 ± 0.7 |
| Food intake at 18 to 30 mo | | |
| Kcalories (kcal/day) | 839.5 ± 196.9 | 857.3 ± 166.7 |
| Protein (gm/day) | 22.2 ± 5.9 | 23.4 ± 4.9 |
| Animal protein (gm/day) | 4.1 ± 3.0 | 3.3 ± 2.4 |
| Fat (gm/day) | 15.3 ± 6.4 | 14.2 ± 5.1 |
| Carbohydrates (gm/day) | 161.4 ± 37.9 | 167.7 ± 31.1 |

Values are expressed as mean ± SD.
*Physical measures are reported as z score transformations with the use of NCHS standards.

critical (1) because previous research has shown that care-giver behaviors affect developmental outcome, whereas SES is a less robust predictor,[15] and (2) because better-nourished children receive more attention and care irrespective of SES.[16] Third, our study included cognitive, motor, language, and play behavior outcomes. Some skills were tested directly in a standardized fashion; others were observed during several visits in a natural setting. This variation in outcome measures allowed testing of the hypothesis that some components of developmental outcome may be more closely tied to nutritional status, whereas others are more strongly influenced by family characteristics.

## METHODS

**Description of the study area.** The study took place in the Embu District of Eastern Province, Kenya. This area included 2059 households, all of which belonged to the Embu tribe and spoke Kiembu. The Embu are small-landholder farmers who produce subsistence and cash crops and keep some livestock. Dwellings are scattered and are adjacent to the families' fields. Most houses are small, two-room structures constructed of mud with thatch or tin roofs. There is no electricity. Social and educational services include primary and secondary schools, health centers, and a network of feeder and dirt access roads. Households are primarily monogamous and nuclear, and include an average of six or seven people. Younger children and toddlers play around the dwellings most of the day, usually in view of their mothers or with a group of children.

**Subjects.** Of the households in the study area, a sample of 292 was selected for participation. Informed consent was obtained from the household head before the start of the study. Of the 292 households, 119 had toddlers who were projected to reach 18 to 30 months of age during the study (January 1984 to August 1985). Of these children, 110 (53 boys) were observed and tested a sufficient number of times for their data to be included. Hearing and vision screening ensured that the toddlers had no auditory or visual problems. Children were not tested or observed when ill.

Anthropometric and food intake data were used to specify the extent of malnutrition in these toddlers. At 30 months of age the mean length for the boys was 83.9 cm (range 77.6 to 92.9, SD = 3.7) and the mean weight was 11.5 kg (range 9.0 to 14.8, SD = 1.2). For the girls, mean length was 82.7 cm (range 74.9 to 89.5, SD = 3.3) and mean weight was 11.0 kg (range 8.1 to 13.3, SD = 1.4). Mean z scores* for length and weight (National Center for Health Statistics [NCHS] standards[17]) are shown in Table I. Only four of the toddlers had z scores greater than 0 for length, and three had z scores greater than 0 for weight. Thirty-five toddlers had weight-for-length z scores greater than 0. The NCHS reference data provide a meaningful comparison because well-fed Kenyan children are at or above NCHS median values.[18] Mean daily food intake during the 18- to 30-month period (shown in Table I) was 857.3 kCal (range 576 to 1279) for boys and 839.5 kCal (range 399 to 1334) for girls. These intakes are substantially less than the recommended food intakes of 1071 and 1032 kCal/day (for male and female toddlers, respectively) established jointly by the Food and Agriculture Organization, the World Health Organization, and United Nations University.

**Procedures.** Assessment included measures of food intake; length and weight; motor, cognitive, and behavioral outcomes; and family characteristics and care-giver interactions. Different enumerators collected data relevant to different domains, and enumerators were unaware of the results of other assessments.

**Food intake.** Information on food preparation and consumption was recorded for 2 consecutive days each month during months 18 to 30. On the morning of the first day, the enumerator weighed all ingredients used in the prepa-

*Negative z scores correspond to measures less than the NCHS mean, whereas positive z scores correspond to measures greater than the mean. For example, a z score of −1 corresponds to a length or weight measure 1 SD less than the mean.

ration of breakfast, lunch, and dinner. Meal portions consumed were recorded for breakfast and lunch. Self-fed snacking was observed between meals.* The enumerator left the house at approximately 6 PM (usually before dinner) but returned the following morning to obtain maternal recall of foods consumed since her absence and to record food intake as for the previous day. On the morning of day 3 the enumerator again obtained a recall report of the foods eaten during the prior evening.

Food composition tables, based on biochemical analyses of main local foods and relevant food tables, were used to determine nutritional constituents of ingested foods. Intake variables calculated were energy (kilocalories per day), total protein (grams per day), animal protein (grams per day), fat (grams per day), and carbohydrate (grams per day). Mean daily intakes of these variables, for the 18- to 30-month period, were used in analyses.

**Physical size and stature.** At 30 months (±2 weeks) of age, assessments of length and weight were conducted by two examiners working independently. If the two measurements were discrepant by more than a predetermined amount, examiners repeated their measurements. The mean of the two or four measurements was recorded. Length measurements were conducted with the child lying supine on a portable wooden measuring board. A portable, battery-operated, digital readout scale was used for weighing.

**Bayley Motor and Mental scales.** At 30 months (±2 weeks) of age the Bayley Motor and Mental scales[20] were administered. Testing was conducted by experienced testers fluent in English and Kiembu. On the Motor scale, two testers observed 16 children simultaneously but scored the tests separately; they differed by one point on two toddlers and had perfect agreement on the remaining 14 children. Modifications were made in the Bayley Mental scale so that it would be more appropriate for the culture and testing conditions of the study.[15] The pictures and objects used for naming were selected from local sources, and the body part items were changed because the local straw dolls used did not have discernible facial features. When each of 16 toddlers was assessed jointly by two testers observing the child simultaneously, there was perfect agreement for 15 scores and a 2-point difference for the remaining score. For both the Motor and Mental scales the total number of items passed, rather than a developmental quotient, was recorded.[15]

*At 18 months of age, approximately 25% of the toddlers were receiving small amounts of human milk. Calories obtained from breast-feeding could not be calculated. By 30 months of age, none of the toddlers were breast fed.

**Table II.** Relationship between food intake and anthropometric status (n = 106)

| Mean daily intake from 18 to 30 mo of age | Length at 30 mo of age | Weight at 30 mo of age |
|---|---|---|
| Total kcalories (kcal/day) | 0.32* | 0.25* |
| Protein (gm/day) | 0.22* | 0.20* |
| Animal protein (gm/day) | 0.32* | 0.08 |
| Fat (gm/day) | 0.36* | 0.13 |
| Carbohydrate (gm/day) | 0.26* | 0.26* |

*$p < 0.05$ (two-tailed).

**Home observation.** Home observations were used to measure home rearing conditions in terms of caretaking and social experiences, and to assess the child's play with objects and expressive language in an unstructured situation. The observer noted any behavioral category that occurred in a 30-second interval; the following 30 seconds were used for recording. Observations were carried out for 90 to 120 minutes every other month throughout the 15- to 30-month period. The following interactive patterns were coded: provides physical care, holds or carries the toddler, touches, talks to the child, and provides social interaction. The toddler's play with objects and verbalizations were also coded. The reliability of these care-giver and toddler observations was satisfactory.[15] The percentage of intervals in which a particular code occurred was averaged across all visits for each social interaction and toddler behavior.

Because play behaviors are predictive of language and intelligence,[21,22] home observations were also used to assess simple, functional, and symbolic play. Simple play included instances of manipulatory (mouthing, fingering, throwing) and relational play (nonfunctional combining of objects such as banging, stacking, lining up). Functional play consisted of instances of using objects in conventional ways. Symbolic play included the use of one object for another or the creation of objects or people not present in the immediate environment (e.g., using a stick as though it were a baby). One of the play codes or a no-play-observed category was coded for each interval, and the mean (percentage of 30-second observational periods with that code) was calculated. Interrater reliabilities for the play variables were $r$ (15) = 0.87, $r$ (15) = 0.84, and $r$ (15) = 0.96, respectively.

**Socioeconomic status, parental IQ, and literacy.** An SES questionnaire designed to be relevant to the Kenya population under study (including questions about farming facilities, landholdings, household possessions, construction of dwellings, and use of community services) was administered. The correlation between local Embu subchiefs'

Table III. Relationship between nutritional variables and developmental outcome

| Nutritional variables | Cognitive measures at 30 months of age | | | | Home observations | | |
|---|---|---|---|---|---|---|---|
| | Bayley Mental score | Play | | | Bayley Motor score | Amount of verbalization | Amount of play |
| | | Simple | Functional | Symbolic | | | |
| Total kcalories | 0.09 | −0.21* | 0.15 | 0.25* | 0.13 | 0.21* | 0.28* |
| Protein | 0.05 | −0.18 | 0.05 | 0.20* | 0.06 | 0.13 | 0.21* |
| Animal protein | 0.14 | 0.03 | 0.00 | 0.25* | 0.03 | 0.26* | 0.33* |
| Fat | 0.19 | −0.06 | 0.09 | 0.25* | 0.13 | 0.28* | 0.36* |
| Carbohydrates | 0.04 | −0.24* | 0.16 | 0.21* | 0.12 | 0.15 | 0.21* |
| Length | 0.25* | −0.24* | 0.05 | 0.13 | 0.29* | 0.26* | 0.21* |
| Weight | 0.29* | −0.17 | 0.08 | 0.11 | 0.30* | 0.18 | 0.11 |

The sample size varies because of missing data for some assessments and ranges from 101 to 110.
*$p$ <0.05 (two-tailed).

ranking of households (based on indigenous criteria) and SES as assessed by the questionnaire was $r = 0.48$ ($p$ <0.001).

The Raven Standard Progressive Matrices[23] were used to assess the performance type of intellectual abilities in both parents. The adult selected the correct pattern to complete a set of pattern matrices. The test measures the ability to observe and organize perceptual detail and to reason by analogy and form comparisons. The correlation between tests scored simultaneously by two testers was $r$ (45) = 0.91 ($p$ <0.001). For analysis purposes, a mean parental Raven score was used.

Paternal and maternal reading and writing skills were assessed. Passages for both tests were selected from Kiembu textbooks used locally and reflected graded levels of difficulty. For both the reading and writing tests a grade level score was calculated, and these scores were combined for both parents to yield an average parental literacy score. Responses of 29 adults were scored simultaneously by two testers; identical scores were obtained in all instances.

## RESULTS

Correlations between nutritional measures and developmental outcomes were computed. Because separate analyses for boys and girls revealed no significant differences, the data were combined.

**Relationship between food intake and anthropometric status** (Table II). Food intake and anthropometric status were consistently associated, with significant correlations between length and all types of food intake, and between weight and the number of kilocalories and grams of protein and carbohydrate consumed. Children who were better fed from 18 months to 30 months of age were taller and heavier at 30 months.

**Relationship between nutritional variables and developmental outcome** (Table III). All correlations between food intake and Bayley Mental scores were nonsignificant, with only the correlation between fat intake and Bayley Mental score approaching significance $r$ (108) = 0.19 ($p$ = 0.055). However, food intake was consistently related to the play measures. The correlations between food intake and symbolic play (an advanced form of play at 30 months of age) were positive and significant in all instances. A relational-manipulational type of play (an immature form of play for 30-month-old children) was negatively correlated with consumption of carbohydrate and kilocalories. Functional play and motor abilities at 30 months were not associated with food intake. However, toddlers who were more verbally expressive and played more with objects from 15 to 30 months of age had a higher nutritional status.

Bayley Mental and Motor scores of toddlers who were taller and heavier were better than those of smaller, leaner toddlers. Taller toddlers were more playful and verbal than their shorter peers. They also engaged in less simple play, but there was no relationship between toddler size and the amount of functional or symbolic play.

**Relationship between nutritional variables and family background–home rearing conditions** (Table IV). To determine whether well-to-do, better-educated parents or parents providing more stimulating rearing conditions were likely to provide more food for their children, we calculated correlations between family background–home rearing conditions and food intake variables. All three family variables were related to fat intake, and SES was related to animal protein and literacy to the number of kilocalories consumed. Of the home rearing conditions, holding or carrying and physical care of the toddler were consistently associated with reduced intake of food. On the other hand, the extent to which the child was touched, talked to, or involved in social interaction was largely independent of level of nutrition. Thus the families who touched their toddlers more often or who provided more verbal or social

**Table IV.** Relationship between food intake and family background–home rearing conditions

| Food intake variables | Family background | | | Home rearing conditions | | | | |
|---|---|---|---|---|---|---|---|---|
| | SES | IQ | Literacy | Provides physical care | Holds or carries | Touches | Talks to | Provides social interaction |
| Total kilocalories | 0.14 | 0.16 | 0.20* | −0.29* | −0.33* | −0.08 | 0.07 | −0.10 |
| Protein | 0.03 | 0.09 | 0.15 | −0.26* | −0.25* | −0.08 | 0.05 | 0.05 |
| Animal protein | 0.36* | 0.17 | 0.17 | −0.12 | −0.19* | 0.09 | 0.23* | 0.11 |
| Fat | 0.39* | 0.23* | 0.23* | −0.19* | −0.26* | 0.01 | 0.18 | 0.02 |
| Carbohydrates | 0.02 | 0.11 | 0.15 | −0.28* | −0.30* | −0.11 | 0.02 | −0.15 |

The sample size varies because of missing data for some assessments and ranges from 104 to 110.
*$p$ <0.05 (two-tailed).

stimulation did not necessarily provide more adequate nutrition.

**Relationship between family background–home rearing conditions and developmental outcome** (Table V). With regard to family background and home rearing conditions, the only significant association was between parental literacy and the Bayley Mental scores. However, this correlation was not significant when toddler length or weight was covaried. On the other hand, toddler size continued to be associated with Bayley Mental score even when parental literacy was covaried.

Of the home rearing variables,* the extent that the toddler was held or carried and talked to showed the most consistent relationship to developmental outcome. Toddlers who were held or carried more often between 15 and 30 months of age performed poorly in all domains. Toddlers who were talked to more often showed more advanced skills in areas of mental development and play but not motor development; they also were more playful and talkative. Symbolic play and playfulness and loquaciousness in the home were related both to nutritional intake and rearing experience, so the question arises whether one of these is the prepotent influence. The correlation between consumption of kilocalories and symbolic play remained significant even when correlated home rearing variables, that is, "talked to" ($r$ [106] = 0.24 [$p$ <0.01]) and "held" ($r$ [106] = 0.21 [$p$ <0.05]), were removed by partial correlation methods. The associations between the child's playfulness ($r$ [106] = 0.28 [$p$ <0.01]) and loquaciousness ($r$ [106] = 0.20 [$p$ <0.05]) and his or her food intake remained significant when the amount of time that the child was talked to was eliminated by partial correlation methods. However, these correlations were no longer significant if the extent that the child was held was covaried.

Correlations between home rearing conditions and developmental outcome seemed more robust than correlations between family background and developmental outcome. When all home rearing variables were forced into a regression equation to Bayley score, no family background variables entered into the regression. However, when family variables were "force entered," social interaction and holding continued to add significantly to the equation.

**Prediction of Bayley Mental score** (Table VI). The major standardized measure used in this study was the Bayley Mental scale, which is predictive of later intelligence in Western populations.[24] To determine which variables best predicted Bayley Mental scores, we calculated a multiple regression by using anthropometric measures, family indexes, home rearing variables, and child characteristics observed in the home. Four variables contributed significantly to the stepwise regression, accounting for 25% of the variance in Bayley scores. In order of entry, these variables were weight at 30 months of age, the extent to which the child verbalized in the previous 15 months, the frequency of social interactions, and the frequency of touching experienced by the child.

## DISCUSSION

In this study we explored the relationship between nutritional variables and developmental outcome in Kenyan toddlers. Food intake was related to the physical development and play skills of the toddlers at 30 months of age. Increased food intake was also associated with increases in total amount of play and verbalization. Furthermore, food intake remained related to these outcomes even when family background–home rearing variables were considered. Cognitive and motor skills, assessed in a more standardized fashion on the Bayley Scales, were not directly related to levels of food intake but were associated

*Correlations between home rearing variables and Bayley scores are slightly different from those reported previously[13] because of small differences in the computational methods used for scoring and samples.

**Table V.** Relationship between family background–home rearing conditions and developmental outcome

| | Cognitive measures at 30 mo of age | | | | Home observations | | |
|---|---|---|---|---|---|---|---|
| | Bayley Mental score | Play | | | Bayley Motor score | Amount of verbalization | Amount of play |
| | | Simple | Functional | Symbolic | | | |
| Family background | | | | | | | |
| SES | 0.15 | −0.07 | 0.05 | 0.05 | 0.06 | 0.09 | 0.00 |
| Parental IQ | 0.19 | −0.03 | 0.17 | 0.14 | 0.10 | 0.08 | 0.10 |
| Parental literacy | 0.19* | −0.12 | 0.11 | 0.17 | 0.17 | −0.06 | 0.04 |
| Home rearing variables | | | | | | | |
| Provides physical care | −0.14 | −0.01 | −0.17 | −0.13 | −0.19 | −0.09 | −0.08 |
| Holds or carries | −0.24* | −0.07 | −0.24* | −0.19* | −0.22* | −0.43* | −0.53* |
| Touches | −0.03 | 0.22* | −0.05 | 0.12 | −0.04 | 0.18 | 0.23* |
| Talks to | 0.20* | 0.14 | −0.02 | 0.23* | 0.06 | 0.37* | 0.22* |
| Provides social interaction | 0.24* | 0.08 | 0.01 | 0.17 | 0.01 | −0.10 | 0.15 |

The sample size varies because of missing data for some assessments and ranges from 101 to 110.
*$p < 0.05$ (two-tailed).

**Table VI.** Prediction of Bayley Mental score at 30 months of age

| Variables entered | $R^2$ change from previous step | $F$ | $p$ |
|---|---|---|---|
| Weight | 0.078 | 9.56 | 0.003 |
| Amount of verbalization | 0.053 | 6.50 | 0.013 |
| Social interaction | 0.067 | 8.27 | 0.005 |
| Touched | 0.048 | 5.92 | 0.017 |
| Total $R^2$ | 0.25 | | |

with length and weight. Length, but not weight, was associated with amount of verbalization and play from 15 to 30 months of age. Correlations between anthropometric status and developmental outcome persisted when the family background–home rearing variables, which were also related to outcome were removed by partial correlation methods.

Anthropometric status and food intake had somewhat different relationships to cognitive outcome at 30 months of age. Food intake was associated with level of symbolic play but not with Bayley score, whereas anthropometric status was associated with Bayley score but not with symbolic play. The difference in relationships might be due to the differing energy levels required for the skills to be demonstrated. The Bayley Scales were administered to the child in such a way that the child needed only to respond. On the other hand, the child had to initiate play to demonstrate skill in this area.

Our results show no direct association between food intake and cognitive skills as measured by the Bayley Scales. However, there is some indication of an indirect path through the child's physical size and, possibly, through other characteristics such as play behavior, playfulness, and loquaciousness. Children who were better fed also played and verbalized more, traits related to abilities tapped by the Bayley Mental scale.

Both family background and home rearing variables were related to outcome. However, home rearing variables were consistently stronger predictors and were related to outcome even when nutritional variables were considered, whereas family background was not. This finding is important for intervention efforts because it suggests that changes in care-giving practices (which would be less costly and time-consuming to effect than changes in SES or parental education) do make a difference for the child. This is also critical for future research efforts directed toward uncovering the relationships among nutrition, social environment, and outcome components. Prior research has tended to focus on more general family background indexes of socioeconomic environment.[2,11,13]

The extent that the toddler was held or carried was negatively associated with development in all domains. Toddlers who were carried a great deal were fed less and were less playful and talkative. It may be that frequently held children compose a subsample of toddlers who develop poorly from an early age, who receive less food, and who are smaller and more sickly. On the other hand, certain families may care for their toddlers by carrying them more often, and this practice may interfere with development. Regardless of the direction of effects, the relationship between holding and both poor developmental outcome[25,26] and reduced food intake[27] has been reported by others.

Our results do not support a theory of differential effects of mild malnutrition on development. Nutritional measurements were not more closely associated with some components of developmental outcome than with others. In addition, socioenvironmental variables did not appear to be differentially related to developmental outcome. This finding is in contrast to those of some studies which suggest that motor and performance skills may be affected more by nutrition,[28,29] whereas language skills are related more to environment.[7] More severe malnutrition or greater variation in environment may be necessary before these differential effects become evident.

The overall results of this study support the hypothesis that mild to moderate malnutrition has deleterious effects on the physical, cognitive, and motor development of children. At the same time, the study demonstrates that other characteristics of the environment, such as the extent of social and verbal interaction, are also important in relation to the child's development.

A project of this magnitude involves the contributions of numerous individuals, only some of whom can be acknowledged. The project director is Doris Calloway. Eric Carter organized the administration of the project, Susan Weinberg directed the collection of the food intake data and A. A. J. Jansen directed the collection of the anthropometric data. Susan D'Souza administered and supervised the cognitive testing. Contributions to the design of behavioral observations were made by Dorthy Cattle and Benjamin Nyaga. Michael Espinosa and Leslie Wanek helped with the data analysis.

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APPENDIX D

# Prediction of Cognitive Competence in Kenyan Children from Toddler Nutrition, Family Characteristics and Abilities

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## ABSTRACT

This study explored the extent to which cognitive competence in 5-year-old Kenyan children was associated with earlier nutritional factors, family conditions and toddler characteristics. Food intake during the 18th to 30th month and physical stature at 30 months were associated with cognitive skills at 5 years. Measures of family background, abilities of the child as a toddler and current schooling were also associated with cognitive abilities at 5 years. These variables influenced development independently so that later cognitive competence was best predicted by a combination of earlier nutritional, family and toddler characteristics.

One of the major lines of research in the study of children has been the investigation of individual differences in abilities. Most research effort has focused on the development of children in industrialized countries despite the fact that more than 50% of the world's children live in developing countries (Werner, 1986). Moreover, the abilities of children in areas where there is a scarcity of resources and employment possibilities may be even more crucial to their later well-being and that of their countries than in areas with greater economic resources.

The study of individual differences among children in developing countries is particularly daunting in that, in addition to the environmental resources usually considered important, nutritional factors have to be investigated. Economic, educational and social resources of families are related to individual differences in the cognitive abilities of children in developed countries where most children are presumably adequately nourished (Bee, Barnard, Eyres, Gray, Hammond, Spietz, Snyder and Clark, 1982; Clarke-Stewart, 1988). Nutritional adequacy is particularly relevant to the development of children in nonindustrialized countries where 50% or more of the children may suffer from mild-to-moderate protein-energy malnutrition (U.S. Department of Health, 1972). In these circumstances, the child-rearing efforts of even socially responsive families may be overwhelmed by chronic undernutrition.

The level of nutrition that a family or community provides for its children is often associated with other family and community

resources (Galler, 1987). Some research suggests that poor nutrition has detrimental effects not completely accounted for by associated environmental characteristics (Freeman, Klein, Townsend and Lechtig, 1980; Johnston, Low, de Baessa and MacVean, 1987). Other data suggest that relations between mild-to-moderate protein-energy malnutrition and development may be attributable to confounded environmental factors (Bogin and MacVean, 1983; Evans, Moodie and Hansen, 1971).

In order to investigate these issues, we are engaged in a large-scale study of the functional effects of mild-to-moderate malnutrition in families in rural Kenya. The project was funded by the United States Agency for International Development following a series of meetings held by the National Academy of Sciences during which it was concluded that there was a pressing need to know more about the effects of mild-to-moderate protein-energy malnutrition on adults and children. The design of these studies has included direct observation and measurement of nutritional, environmental and child characteristics. To date, we have focused on the correlates of cognitive abilities in a group of toddlers followed from 15 to 30 months (Sigman,Neumann, Carter, Cattle, D'Souza and Bwibo, 1988; Sigman Neumann, Baksh, Bwibo and McDonald, 1989) and a group of school-age children (Sigman, Neumann, Jansen and Bwibo, 1989) seen over the course of one year. The current study described in this paper bridges the gap between these prior studies in that the toddlers seen initially were followed to school age.

In this study the original toddler sample was retested at 5

years using the same cognitive measures as had been used with the school-age children. This follow-up was aimed at determining which early nutritional and environmental variables predicted cognitive competence at 5-years and at testing the continuity of child abilities. This allowed replication and extension of the findings noted with the school-age children with nutritional data collected earlier in life, rather than concurrently. This study also allowed an examination of the association between early home rearing patterns and the school-age cognitive measure.

We hypothesized that both nutritional adequacy and family characteristics would contribute to the child's cognitive scores at 5 years. Prior research has shown that both nutritional and environmental variables are related to later outcome in populations suffering from mild-to-moderate malnutrition (Freeman et al., 1980; Johnston et al., 1987). Total caloric intake was expected to have some association with subsequent cognitive scores. Toddlers who were fed more were more talkative and playful by 30 months of age which was likely to be advantageous to their continuing cognitive development. We hypothesized that the strongest relations would be between cognitive score and animal protein and fat as these were the nutrients most highly correlated with cognitive scores for the Kenyan school-age sample as well as with amount of play and verbalization for the Kenyan toddlers.

The kind of caregiving provided to the toddlers was also expected to be important for later cognitive skills. During the toddler years, children who were talked to and interacted with more

socially were more cognitive and verbally competent than toddlers who were less involved in verbal and social interchanges. Toddlers who were held, carried, and given more physical care tended to develop less well (see also Goldberg, 1977). In addition, the measures of toddler abilities were anticipated to be related to cognitive competence. Continuity of abilities across similar age spans has been reported previously (Honzik, 1983; McCall, 1983; Wilson, 1978).

## METHODS

### Study population

The geographical location and cultural habitat of the Kenyan population under study has been described extensively elsewhere (Sigman et al, 1988). The study area was located on the southeastern slopes of Mt. Kenya in the Embu district of central Kenya. Households involved in the study belonged to the Embu tribe and spoke Kiembu. The Embu reside in 2 to 3 room dwellings located adjacent to the families' fields. The production of subsistence and cash crops and the tending of some livestock are the primary means of support for most families.

Two hundred forty-seven households within the study area were selected for and completed participation. Of these 110 had toddlers who participated in the initial phase of the study. At the 5-year follow-up, 98 of these children were located. Of these, eight could not be tested because of parental refusal. An additional seven children failed to cooperate with the cognitive tests. The 27 children who were not tested at 5 years did not

differ from the 83 children who were tested on family SES, parental literacy, parental Ravens score, total Kcals consummed, length or weight at 30 months or Bayley Mental score at 30 months.

Procedures - 18 to 30 month measures

Nutritional adequacy was measured by food intake and toddler length and weight. Direct observation and weighing of food intake was conducted for 2 consecutive days each month during the 18th to 30th months. A trained enumerator measured and weighed recipe ingredients and observed meal portions and snacks given to the toddler from 7:00 am to 6:00 pm. On the following morning the enumerator returned, interviewed the mother about food consumed since last evening and continued her observations as of the day before. She returned again on the 3rd day to obtain maternal report of the foods eaten since the prior evening.

A small validation study was conducted on 10 households to assess whether this retrospective accounting of the previous evening's meal was biased. An additional enumerator recorded food intake throughout the day and remained until late in the evening so that all food intake was directly observed. There was excellent agreement between the recordings made by the enumerators in these households.

In order to determine nutrient composition of the foods consumed, food composition tables were developed. These were based on biochemical analyses of main local foods and use of relevant food tables. Food intake variables were mean intake per visit of Kcals (Kcal/day), protein (g/day), animal protein (g/day), fat

(g/day) and carbohydrates (g/day). For the purposes of data analysis a principal components analysis was calculated of these intake variables for the period from 18 to 24 months and the period from 24 to 30 months. Three factors accounted for most of the variance in the nutritional data. The first factor reflected food intake from 18 to 24 months with a somewhat heavier loading of carbodydrate and protein intakes than of fat and animal protein intakes during the same period. The second factor reflected carbohydrate and protein intake from 24 to 30 months, and the last factor reflected only animal protein and fat intake over the course of the year.

Measures of length and weight were made on a monthly basis. Measurements were conducted by two independent examiners and measurements discrepant by more than a predetermined amount were repeated. The means of the two (or four) measures were used in the analyses. Length was recorded with the child lying supine on a portable wooden measuring board. A portable battery operated digital read-out scale was used for weighing. Repeat reliability was good, $r(42)=.81$ for length and $r(41)=.91$ for weight. For the purposes of this study, measures at 30 months ($\pm$ 2 weeks) were used.

In order to assay iron levels, samples of blood were drawn from the toddlers at some point during the year that they were followed. Hematocrits and levels of hemoglobin and ferritin were measured.

Home observations of caregiver and toddler behaviors were conducted every other month during the 15th to 30th months. Observations were made for 120 minutes using a time sampling procedure with a 30 second observational period followed by a 30 second recording period. In order to describe home rearing conditions and the interactive patterns of caregivers, six caregiver behaviors were coded. These were 1) physical care - including feeding, washing and changing, 2) holds or carries, 3) touches, 4) social interaction - consisting of periods when the child was actively involved in an ongoing social exchange, 5) talks to child, and 6) responsiveness to the toddler's verbalizations.[1] Inter-rater agreements calculated with Pearson correlation coefficients ranged from $r(15)=.85$ to .98, $p<.01$ in all instances.

The percentage of intervals in which a code occurred during a visit was calculated for each visit during the 15th to 30th months. From these data, a single mean score for each caregiving variable was composed. In addition, a principal components analysis was calculated for the caregiving variables calculated separately from 15 to 24 months and from 24 to 30 months. The first four factors accounted for 61% of the variance in the cargiving variables. The first factor reflected verbal stimulation and responsiveness to verbalizations in the earlier age period while the second factor reflected verbal stimulation, responsiveness, and level of social

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[1] Except for social interaction which usually involved a peer or sibling, the majority of caregiving was provided by the mother. Older sisters also provided a significant amount of care (see Sigman et al, 1988 for a detailed description).

interaction in the older age period. The third factor reflected the amount that the child was carried or cared for in the early period while the fourth factor reflected the amount that the child was carried or cared for in the the later period.

These same observations were used to assess toddler behaviors that could not be measured in structured testing. Five toddler behaviors coded included 1) toddler vocalization, 2) toddler play - including all types of play activity, 3) simple play - instances of simple manipulation such as mouthing, waving and throwing and nonfunctional combining of objects such as banging two objects or stacking, 4) functional play - instances of using objects in conventional ways and 5) symbolic play - instances of using one object as if it were another or the invention of objects or people not present. Pearson coefficients for independent observers ranged from $r(15)=.34$ to .96, $p< .01$ in all instances. For data analysis purposes the means (percentage of observational periods with that code) for each variable were calculated. Amount of toddler vocalizations and play were assessed throughout the 15- to 30-month period whereas the specific play behaviors were measured only at 30 months.

Family background characteristics were also considered. An SES questionnaire designed to be relevant to the Embu population under study was administered quarterly during the child's 18th to 30th months. The last of these quarterly SES measures was used in the present study. The SES measure included questions about land, farming and household assets, use of social services and community

involvement. These were weighted and summed to yield a total SES score. Test-retest reliability for SES scores obtained within one week of each other was $r(42)=.95$, $p < .001$.

Census data was used to determine household composition. Any individual residing in the child's home during one or more of the quarterly periods was included. The number of adults, number of children $\leq$ 6 years, 7 to 12 years and 13 to 18 years was calculated.

Trained Kenyan experimenters visited each parent in the home and assessed parental IQ and literacy sometime during the toddlers 18th to 30th months. Parental IQ was estimated with the Raven's Progressive Matrices (Raven, 1960). This assessment requires the subject to select the correct geometric pattern to complete a set of patterns. Performance-type intellectual skills tapped by this largely language-free test include the ability to observe and organize perceptual detail and to reason by analogy and form comparisons. All items were administered to each adult and the total number of correct patterns was computed. A mean parental IQ score was calculated. The correlation between tests scored simultaneously by two testers was $r(45)=.91$, $p<.001$.

Literacy was assessed by having each parent read and answer questions and transcribe dictated passages from local school textbooks (written in Kiembu). In the reading test the adult read passages out loud and responded orally to comprehension questions. Writing passages were dictated twice. Reading and writing passages were discontinued when more than a predetermined number of errors

occurred. The correlation between responses scored simultaneously by two testers was $r(27)=1.0$, $p<.001$. For both the reading and writing tests grade level scores were calculated and these were summed across both parents to yield an average parental literacy score.

Bayley Mental and Motor Scales (Bayley, 1969) were administered at 30 months (± 2 weeks). Bayley Mental items from #116 on were assessed with some exclusions and modifications. In order to make the test more relevant to the Kenyan culture, pictures and objects used in the naming items were chosen from local sources and items requiring the recognition of a watch from successive drawings were excluded. In addition, local straw dolls were used because the children were apprehensive of the standard Bayley dolls. The local dolls did not have discernible facial features so items requiring identification of body part items were changed accordingly. Bayley Motor items from #57 on were assessed with the exclusion of those items requiring a walking board or stairs. The total number of items passed for both Mental and Motor tests was recorded. Bayley Mental and Motor Scales were administered by one of four examiners all with prior experience. On the Bayley Mental Scales different examiners observing the child simultaneously had perfect agreement of 15 of 16 scores with a two-point discrepancy on the remaining score. On the Motor Scales there was perfect agreement on 14 of 16 scores with a one-point discrepancy on two toddlers.

Procedures - 5-year assessments

The cognitive tasks were administered to the children at 5 years, 3 months (± 2 weeks) of age. The Verbal Meaning Test was similar to the Peabody Picture Vocabulary test (Dunn and Dunn, 1981) but with pictures used previously in East Africa. The child was presented with four pictures and asked to point to the one named by the experimenter. Simpler items involved discrimination between common nouns whereas more advanced items required knowledge of abstract concepts. The Raven's Colored Progressive Matrices (Raven, 1965) was used to assess performance type abilities. The child was presented with a matrix-like arrangement of symbols and completed the matrix by selecting the appropriate missing symbol from a group of symbols. As for the adults, the test measures the ability to organize perceptual detail and to reason by analogy and form comparisons.

For both the Verbal Meaning Test and Raven's Matrices, all items were administered to each child and the total number correct on each was calculated. When testing was observed simultaneously by two separate examiners, the correlation between scores was $r(10)=.93$, $p<.05$ for the Verbal Meaning Test and $r(10)=.99$, $p<.05$ for the Raven's Matrices. Prior use of these tests with slightly older Embu school-children indicates that they have stability over time and construct validity when compared to school examination scores (Sigman et al, in press). Since scores on the Verbal Meaning test and the Raven's Matrices were correlated $r(81)=.36$, $p<.001$, the scores were combined to yield a composite cognitive

score as used previously with the school-age children.

At the time of the child's cognitive testing parents were asked how many months (if any) their child had attended school. Most children (86%) had not yet begun school. Months in school averaged 0.6 (SD=1.86, range=0 to 10). For the purpose of data analysis, school attendance was transformed into a dichotomous variable reflecting whether or not the child had attended school.

## RESULTS

Males and females were not significantly different in mean cognitive scores nor were any gender differences in correlations between early measures and the cognitive scores statistically significant. Thus, data were combined for the males and females.

### Nutritional indices

At 30 months of age the mean length for males was 84.1 cm (*SD* =3.6) and the mean weight was 11.4 kg (*SD* = 1.2). For the females, mean length was 82.9 cm (*SD* = 3.2) and mean weight was 11.0 kg (*SD* =1.2). Mean *z* scores for length and weight using NCHS standards (Hamill, Drizd, Johnson, Reed, Roche and Moore, 1979) are shown in Table 1. (Insert Table 1 about here.) Of the 80 toddlers with anthropometric data, three of the children had *z* scores above 0 for length and none had *z* scores above 0 for weight. Twenty-five toddlers had weight for length *z* scores above 0.

Standard deviations of *z* scores (see Table 1) and distribution curves suggest that nutritional status was normally distributed with enough variation so as to provide valid results.

A substantial proportion of the sample would have to be described

as at least moderately undernourished based on their size. Thirty-eight children had z scores less than -2.0 for length, 24 had z scores less than -2.0 for weight and none had z scores less than -2.0 for weight for height. The NCHS data upon which the z scores are based strongly suggest that these children are undernourished as opposed to genetically distinct since well-fed Kenyan children residing in wealthy rural or urban families are at or above NCHS median values (Stephenson, Latham and Jansen, 1983).

Mean daily food intake during the 18th to 30th months is shown in Table 1. The mean consumption of 850 Kcal for males (range=576-1279) and 860 Kcal for females (range=399-1334) is substantially below the recommended KCal/day intakes of 1071 for males and 1032 for females estimated for moderately active toddlers of this size (FAO/WHO/UNU, 1985) although some children were eating adequately. However, the anthropometry and food intake data support the conclusion that a substantial part of this sample was mildly-to-moderately malnourished.

As expected, food intake during the period from 18 to 30 months and physical stature at 30 months were significantly correlated. Length at 30 months was associated with all the food intake variables, $r(106)=.22$ to $.36$, $ps<.05$. Weight at 30 months was associated with overall energy intake as well as intake of protein and carbohydrates, $r(106)=.20$ to $.26$, $ps<.05$.

Correlations between the nutritional factors and scores on the 5-year cognitive tests were computed. Cognitive scores were associated with both the first factor reflecting overall food

intake from 18 to 24 months, $r$ (81)=.24, $p$<.03, and with the third factor reflecting fat and animal protein intakes over the course of the year, $r$ (81)=.33, $p$<.002.

Since all the nutrients loaded on the first factor, it was impossible to determine whether there was any contribution made by nutrients other than fat and animal protein. For this reason, correlations were computed between the various food intake measures computed for each six month period and cognitive score. As can be seen from Table 2, overall energy intake between 18 to 24 months and the level of all the nutrients except carbohydrates was associated with subsequent cognitive score. When a hierarchical regression was computed with fat and animal protein forced into the regression first, protein level no longer was associated with cognitive score. On the other hand, fat and animal protein continued to contribute to the regression when protein was entered first. These analyses suggest that the association between the first factor and cognitive competence was mostly due to levels of fat and animal protein intake. As can be seen from Table 2, fat and animal protein intakes from 24 to 30 months were also predictive of subsequent cognitive performance. (Insert Table 2 here.)

There were also significant associations between the physical measures at 30 months and 5-year cognitive score (see Table 2). Children who were taller and heavier at 30 months did better on the cognitive composite 3 years later. There were no significant associations between iron levels and later cognitive competence.

Previous nutritional status

Given that food intake was associated with later cognitive score, the question arises whether the association reflects nutritional factors operating before the infant reached 18 months of age. In order to address this issue, correlations were computed between height and weight when the children entered the study and cognitive score at 5-years of age. Because all the toddlers were not measured exactly at 18 months, $z$ scores from the first measurement made after the child reached 17 months were used. Cognitive score was correlated significantly with initial weight and nearly significantly with initial height (See Table 2) Height was predictive of the amount that the child would be fed in the following year both in terms of the second food factor, $r(108)=.22$, $p<.05$, and the third food factor, $r$ $(108)=.29$, $p<.05$. Weight predicted the level of fat and protein over the course of the year as reflected in the third food factor score, $r$ $(108)=.19$, $p<.05$. Given that initial height and weight predicted later cognitive abilities, a hierarchical regression was calculated in which initial height and weight were force entered. The third food factor score continued to enter the regression to cognitive score. When the third food factor score was force entered into the regression first, initial weight continued to enter the regression significantly. Thus, these results showed that both initial nutritional status as reflected in the toddler's weight and the intake of fat and animal protein over the course of the period from 18 to 30 months independently contributed to the variance in

cognitive scores at 5-years of age.

Family, home rearing and early educational factors

Correlations were computed between family and caregiver characteristics and 5-year measures. (Insert Table 3 here.) Family background variables were related to cognitive performance. Children from households of higher SES with more literate parents who performed better on the Raven's matrices had higher cognitive scores than their less advantaged peers.

Home rearing variables were only minimally related to cognitive competence. None of the caregiving factors was associated with later cognitive scores. In terms of the individual mean scores for the caregiving variables, only the amount of physical care was predictive of later cognitive abilities, $r$ (81) = -.24, $p$ <.05. Toddlers who received more frequent physical care (e.g., feeding, washing, putting to sleep) were less cognitively advanced at 5 years.

Relations between early schooling and cognitive competence were also examined. Children who had attended school performed better on the cognitive measure than children who had no schooling (see Table 3). However, these children also tended to be from homes of higher SES, with more literate and intelligent parents. In order to determine if early schooling had any effect beyond these related family characteristics, a regression was calculated. After force entering all family variables which correlated with 5-year cognitive competence (SES, parental literacy and Raven's score and physical care), school attendance did not contribute

significantly. Thus, this limited schooling experience had little effect on cognitive abilities independent of other environmental factors.

Toddler variables

Of the measures taken of the toddlers, the total amount of vocalization during the 15th to 30th months $r(81)=.22$, $p<.05$ and Bayley Mental score $r(80)=.26$, $p<.05$ were predictive of the 5-year cognitive composite measure. Motor skills and amount and type of play (simple/manipulation, functional and symbolic) were not correlated with cognitive outcome.

Predicting cognitive competence

Level of nutrition was associated with other family economic and educational characteristics in this sample as is usually true (Galler, 1987). As discussed in our previous paper, fat intake was significantly correlated with SES, parental IQ and literacy as with the amount that the child was held and cared for. Intake of animal protein was also associated with SES and the percentage of time that the child was held and carried. Children who were poorly fed were held more and provided with mor physical care than adequately nourished children.

In order to test whether nutritional factors contributed independently to cognitive skills beyond the associated environmental effects, a regression was calculated in which all family background, caregiving and schooling variables were entered first. These variables accounted for a total $R^2$ of 0.29 in 5-year cognitive score. However, animal protein continued to add

significantly to the regression equation, increasing the $R^2$ value to 0.36 ($F$=6.68, $p<.05$).

To test the effects of family background, caregiver and schooling variables above and beyond those of food intake and anthropometric status, an additional analysis was performed. When all nutritional and anthropometric variables were forced entered into the regression equation first, they accounted for a total $R^2$ of 0.27. With these variables force-entered, parental literacy continued to contribute significantly to the regression equation increasing the $R^2$ value to 0.31 ($F$=4.68, $p<.05$). Thus, the nutritional and environmental resources of the family were independently influential.

Nutritional intakes might have different effects on children's development depending on the economic and educational resources of the family. To assess such interaction effects, two hierarchical regressions were calculated to determine whether interaction factors would contribute to the regression with 5-year cognitive score. Neither the interaction of SES x animal protein nor of parental literacy x animal protein added significantly to these regression equations.

In order to determine which set of variables best predicted cognitive competence at age 5 years, a stepwise multiple regression was calculated. When early nutritional variables, family background, caregiver characteristics, schooling and toddler measures were considered, three variables explained 30% of the variance. (Insert Table 4 here) In order of entry these three

variables were animal protein, SES and Bayley Mental score. Thus, 5-year cognitive competence was best predicted by a combination of early nutritional factors, family background and toddler characteristics.

## DISCUSSION

Results of this followup generally support the previous findings that both nutritional and environmental conditions relate to the cognitive skills of the school-age child. Early food intake and measures of length and weight at 30 months predicted cognitive skills 3 years later. Environmental variables, especially relatively stable family characteristics such as SES, parental literacy and IQ, were also related to cognitive skills. Furthermore, both nutritional and environmental factors added to prediction of cognitive outcome even when the effects of the other had been considered. These results are consistent with other studies which imply that both nutritional and environmental factors related to childhood abilities (Freeman et al., 1980; Johnston et al., 1987). They are also consistent with findings noted previously in the Kenyan study. In the Kenyan school-age children, food intake measured concurrently was directly associated with cognitive scores as were family characteristics including parental literacy and SES (Sigman, et al., 1989). In the toddlers, food intake was related to the amount of verbalization and play, and length and weight were associated with Bayley Mental score (Sigman et al., 1989). Environmental variables also mattered, but for the toddlers, caregiving variables rather than parental IQ, literacy

and SES were critical.

Both food intake and anthropometric status related to cognitive score at 5 years. Total level of calories available to the toddler between 18 to 24 months was predictive of later cognitive skill. The amount of fat and animal protein consumed by the toddler was important over the course of the year and the contribution of fat and animal protein was independent of the contribution made by the educational and financial resources of the family. Fat and animal protein were also the food values mostly closely associated with outcomes in the previous Kenyan studies (Sigman et al., 1989). Associations between fat and animal products (but not total Kcal) and cognitive outcomes have also been reported in the Mexican branch of this study (Pelto, Allen, Chavez, Martinez, & Finley, 1989).

It is difficult to compare these findings with those from other studies. A comparison of results would require information on the base rates of nutrients, including animal protein and fat, as well as information on the physical stature of the various groups. Very few studies have been able to measure levels of all these nutrients, and the distinction between protein and animal protein has rarely been possible. The INCAP investigators (Engle, Irwin, Klein, Yarbrough and Townsend, 1979; Klein, 1979) generally report that supplemental caloric intake, rather than total diet calories or protein intake, was the best predictor of physical growth and cognitive development. In this study, the supplement was atole, described as being composed mostly of corn which would

seem to have little animal protein. In contrast to the INCAP findings, Rush (1984) observed longer play episodes and more efficient habituation in a group of 12-month-olds whose mothers had been provided protein supplements during pregnancy as contrasted with infants whose mothers had been provided mostly calories. However, the protein supplemented group also received more calories than the group supplemented only with calories.

The findings in the Kenyan study suggest that diet quality is as important for these toddlers as diet quantity. The diet quality markers that emerge are fat and animal protein. Both fats and animal protein would improve the energy density of the diets, perhaps making it possible for children to obtain more calories in a tolerable volume. These foods could also exert an effect in a more specific way, by providing essential nutrients otherwise low in the diet. It is clear that the effects cannot be attributed to iron deficiency since there were no association between blood levels of iron and cognitive scores. The current hypothesis to be tested is that the deficit is in other micronutrients rather than in essential amino acids since total protein intake was close to NCHS standards given the size of the toddlers.

Of course, another possible explanation is that level of animal protein and fat may be markers of family environment that are even more sensitive than SES, parental IQ, and parental literacy. In this case, the contribution of the family may be in some sphere other than nutritional although we have tried to account for possible contributions by measuring home interactions,

SES, and parental cognitive skills. Two empirical approaches to this problem of interpretation suggest themselves. First, an attempt to specify the particular nutrients associated with cognitive skills would be useful and this is in progress. Second, a supplementation study in which the nutrients found in animal products were increased would be very valuable.

The results of this follow-up suggest that earlier nutritional adequacy has effects on school-age children. In our view, the most probable explanations for nutritional effects on cognitive development involve the level of activity and exploration that children can use in learning. The importance of the associations of food intake with the play and verbal skills of the toddlers cannot be minimized. Toddlers with more limited play and verbal skills are likely to learn less so that their cognitive achievements may be affected by age 5-years. Concurrent nutrition seems to associated with cognitive abilities above and beyond the association of earlier nutrition. Earlier nutrition as reflected by weight at entry into the study was associated with later cognitive abilities, but food intake from 18 to 30 months added to this association. Moreover, while fat and animal protein were associated with subsequent cognitive score for this sample, the concurrent correlations between fat and animal protein with cognitive scores for the school-age children were higher (Sigman et al., 1989) with the difference in the size of the correlations approaching significance ($p<.07$). Thus the current food consumption of the child appears to contribute to the child's

functioning beyond previous nutritional status. On the other hand, it is more than likely that nutritional status remains stable over childhood so that children who are fed poorly at one age are fed poorly at other ages and/or that children with decreased body stature require less food subsequently. In support of this a subsample of children did appear to maintain their relative physical status over the 3-year period.[2] In addition, supporting the hypothesis of stability in feeding patterns across age, we have previously reported a significant association between caloric intake for 41 toddler/schcol-age siblings (Sigman et al, 1989).

Environmental variables, such as SES, parental IQ and literacy, were associated with cognitive scores. This finding is supported by other studies which report effects of these type of variables on cognitive outcomes particularly as measured in later childhood (Clark-Stewart, 1988; Longstreth, Davis, Carter, Flint, Owen, Rickert and Taylor, 1981). The nature of the family characteristics related to the child's behavior and abilities changed from 30 months to 5-years. Socioeconomic and educational qualities of the the families were more strongly associated with cognitive scores at 5-years. It could be that the effects are cumulative for these family characteristics, which are relatively stable across time. Alternatively, the immediate caregiving environment may be more important for toddler development than such

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[2] Height and weight were remeasured at 5 years for a subsample of 45 children. Correlations between length and weight at 30 months and at 5 years were $r(43)=.73$, $p<.001$ and $r(43)=.78$, $p<.001$, respectively.

distal factors as parental literacy. Some families may be able to provide responsive and stimulating interactions in the early years which protects the toddler somewhat from the limited nutritional and educational diet. However, by age 5 years, the nature of family contributions and child abilities may change so that talking and socializing with the child are not enough and additional support for educational development may be necessary. Family styles of caregiving may influence children to some extent but they may not be able to protect children from nutritional deprivation or overcome the influence of reduced family economic and educational resources.

Toddler measures of total vocalization and Bayley Mental score were related to cognitive outcomes at 5 years. This is consistent with prior reports which document correlations between language skills in the 2nd year and later cognitive skills (McDonald, Sigman and Ungerer, 1989) and with reports of small but consistent correlations between the 30-month Bayley Mental score and later intelligence (Honzik, 1983; McCall, 1983; Wilson, 1978). In contrast to some findings which report relations between type of play and subsequent cognitive skills (McDonald et al., 1989), the frequency and sophistication of play during the toddler years was not associated with cognitive competence at 5 years.

All the results to date suggest that cognitive competence in these Embu children of rural Kenya is associated with a variety of forces as is true for children in other parts of the world. The extent to which any of these forces is causally linked to

development cannot be stated unequivocably with any single set of studies or research paradigms. The correlational approach used in these studies leaves many questions open to interpretations. Intervention studies have their own disadvantages in terms of possible self-selection of subjects for particular conditions, lack of information about baseline rates of nutrition, and associated changes that accompany food supplementation. However, the correlational approach used in this study has identified certain nutritional and family characteristics which could be the focus of intervention. Finally, the social and research significance of these findings would be enchanced by any attempt to alter the severe nutritional, economic and educational limitations that some of these children experience.

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Susan D'Souza contributed uniquely to this component of the project by independently administering the collection of follow-up data. Eric Carter and Michael Baksh were administrators of the project, Susan Weinberg directed the collection of the food intake data,and A.A. Jansen was responsible for the collection of the anthropometric data. Contributions to the observations of caregiver and toddler behaviors were made by Dorothy Cattle and Benjamin Nyaga. Michael Espinosa carried out the data analysis.

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Table 1

Mean Nutritional Indices for Male and Female Toddlers

| | Females (n=46) | | Males (n=37) | |
|---|---|---|---|---|
| | z Scores* | | z Scores* | |
| | Mean | SD | Mean | SD |
| Physical Measures | | | | |
| Length at 30 months | -1.88 | 0.9 | -1.79 | 1.0 |
| Weight at 30 months | -1.48 | 0.9 | -1.52 | 0.8 |
| Weight for Length | -0.37 | 0.8 | -0.51 | 0.7 |
| Food Intake | | | | |
| 18 to 30 Months | | | | |
| Kcals (Kcal/d) | 860.3 | 198.0 | 850.4 | 179.7 |
| Protein (g/d) | 22.3 | 6.1 | 22.8 | 5.0 |
| Animal Protein (g/d) | 4.2 | 3.0 | 3.4 | 2.6 |
| Fat (g/d) | 15.9 | 6.6 | 14.4 | 5.8 |
| Carbohydrates (g/d) | 165.4 | 37.5 | 165.8 | 32.3 |

*Physical measures reported as z score transformations using NCHS standards

Table 2

Correlations between Nutritional Indices

and 5-Year Cognitive Scores

| Physical Measures | Initial | 30 Months |
|---|---|---|
| Length | .21 | .25* |
| Weight | .28* | .23* |
| Weight for length | .19 | .17 |
| Food Intake | 18-24 Months | 24-30 Months |
| Kcals | .27* | .03 |
| Protein | .25* | .02 |
| Animal Protein | .33* | .32* |
| Fat | .38* | .25* |
| Carbohydrates | .18 | -.05 |

*p<.05 (two-tailed)

Table 3

Relations Between Family and Home Rearing

Characteristics and 5-Year Cognitive Scores

| Family Characteristics | Cognitive Score |
|---|---|
| SES | .31* |
| Family Composition # of | |
| Adults | .20 |
| 13-18 Year Olds | .08 |
| 12- 7 Year Olds | .09 |
| ≤ 6 Year Olds | -.02 |
| Parental IQ | .27* |
| Parental Literacy | .34* |
| Early Schooling | .28* |

*n*'s range from 79 to 83

*$p<.05$ (two tailed)

Table 4

Multiple Regression to 5-Year Cognitive Score

| Variables Entered | $R^2$ Change from Previous Step | F | p |
|---|---|---|---|
| Animal Protein | 0.166 | 18.8 | 0.0001 |
| SES | 0.075 | 8.5 | 0.005 |
| Bayley Mental Score 30 months | 0.062 | 7.1 | 0.01 |
| Total $R^2$ | .303 | | |

APPENDIX E

# Cognitive Abilities of Kenyan Children in Relation to Nutrition, Family Characteristics, and Education

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SIGMAN, MARIAN; NEUMANN, CHARLOTTE; JANSEN, AKE A. J.; and BWIBO, NIMROD. *Cognitive Abilities of Kenyan Children in Relation to Nutrition, Family Characteristics, and Education.* CHILD DEVELOPMENT, 1989, 60, 1463–1474. The purpose of this study was to determine whether nutritional factors, family characteristics, and the duration of schooling were associated with cognitive and attentional capacities in children growing up in rural Kenya. Food intake was measured by direct observation and weighment twice monthly over the course of a year. Families were characterized in terms of socioeconomic status and the literacy of the parents. Children who were better nourished had higher composite scores on a test of verbal comprehension and the Raven's matrices. Better-nourished females were more attentive during classroom observations than malnourished female schoolchildren. Family characteristics and duration of school participation were associated with cognitive abilities for both boys and girls. For the children considered as a group, cognitive scores were best predicted by a combination of factors including duration of schooling, food intake, physical stature, and SES.

More than 50% of the world's children live in developing countries, but influences on the cognitive skills of these children have been investigated far less than have influences on the cognitive skills of children in developed countries (Werner, 1986). Malnutrition is a problem in many developing countries, and estimates are that 48% of children in Africa are poorly nourished (Pollitt, 1988). However, there is only limited understanding of the impact of malnutrition, particularly of mild to moderate undernutrition, which is far more prevalent than severe malnutrition, on the cognitive and attentional skills of children.

One of the major reasons for the relative paucity of information about the effects of nutrition is the problem of assessment. Severe malnutrition can be identified fairly easily by the child's physical appearance, so that the serious consequences of severe malnutrition have been documented (Galler, Ramsey, Solimano, Lowell, & Mason, 1983; Hertzig, Birch, Richardson, & Tizard, 1972; MacLaren, Yatkin, Kanawati, Sabagh, & Kadi, 1973; Monckeberg, 1968). On the other hand, undernutrition can only be identified by measuring nutritional status in subtle ways. Many studies have relied on anthropometric measurements of children as nutritional indi-

This research is a component of a larger study entitled "Energy Intake and Human Functioning: Nutrition Collaborative Research Support Program" carried out in Kenya, Egypt, and Mexico and supported by USAID Contract no. DAN 1309-G-SS-80. The project director is Doris Calloway. A project of this magnitude involves the contribution of numerous individuals, only some of whom can be acknowledged. Eric Carter organized the implementation of the design and Michael Baksh continued its administration. Susan Weinberg directed the collection of the food intake data. Susan D'Souza administered and participated in the cognitive testing carried out by Annet Nyaga, Mary Paul, Lucy Nyaga, and Betty Kaunda. Contributions to the behavioral observations were made by Dorothy Cattle and Benjamin Nyaga. The design of this component benefitted from the wise counsel of Tiffany Field, Theodore Wachs, Emmy Werner, and Marian Radke-Yarrow. Data analysis was partly supported by the World Bank, Washington, D.C. Send reprint requests to the first author at 68237, Department of Psychiatry, UCLA Medical School, Los Angeles, CA 90024.

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ces because of the difficulty of assessing food intake (Agarwal, Upadhyay, Tripathi, & Agarwal, 1987). However, an individual's body size is affected by a variety of factors other than food intake, such as genetic predisposition and health. Some studies have measured food consumed through recall, but dietary recall tends to be inaccurate. The food supplementation studies have produced evidence of a somewhat weak relation between food intake and cognitive development (Pollitt, 1987) partly because the amount of food consumed beyond the supplementation is not always known. The need is for studies in which observation and weighing of food are made on a regular basis.

The present study is part of a large program of research undertaken in Kenya, Egypt, and Mexico to investigate the functional effects of substandard levels of food-energy intake in the range of mild to moderate deprivation. The rationale for this aim emerged from a series of meetings sponsored by the U.S. National Academy of Sciences in which it was agreed that the most common form of malnutrition is due to insufficient intake of food overall, expressed in aggregate as insufficient intake of energy. Several target populations were selected for study: pregnant women, infants from 3 months conceptional age to 6 months postnatal age, toddlers from 18 months to 30 months, and school-age children. The research plan was designed to test six main sets of hypotheses. For the school-age children, the hypothesis was as follows: Food intake of the child between 7 and 9 years affects his or her body weight, morbidity, and behavioral and cognitive performance (Calloway, Murphy, & Beaton, 1988). This article reports on the relations between food intake and cognitive performance.

A second limitation of many studies of undernutrition is that other environmental characteristics have not been measured simultaneously. Several researchers have suggested that the effects of nutrition can be understood only in terms of the family and school environments provided for children (Johnston, Low, deBaessa, & MacVean, 1987; Ricciuti, 1988; Winick, Meyer, & Harris, 1975). The kinds of economic and educational resources available to the family and child are likely to influence the learning experiences of the child both in and out of school. Socioeconomic and educational levels of families are strongly associated with cognitive performance of children in countries where variations in nutritional intake and level of schooling are limited. The relations between family characteristics and childhood cognitive abilities have not been investigated very often in developing countries, particularly in relation to nutritional adequacy and schooling.

The issue of measurement of family and child characteristics is a complex one. The socioeconomic and educational status of the family can be assessed only with measures designed for the particular cultural milieu so that the validity of the measures is often unknown. Child cognitive abilities must be reflected in activities that are appropriate to the cultural demands on the child but still have established reliability and validity. Studies of nutritional interventions, such as the project in Guatemala (Barrett, Radke-Yarrow, & Klein, 1982; Klein, Irwin, Engle, & Yarbrough, 1977), invested a great deal of effort in designing outcome assessments. In the project reported in this article, there was an additional constraint in that the study was carried out simultaneously in three different countries so that cognitive measures had to be used that tapped similar processes but were still appropriate for the children in the three countries. In addition, the aim was to assess not only the child's cognitive skills but also the child's sustained attention to classroom activities.

For the 7- and 8-year-old child, the development of cognitive skills is often focused on most directly in the context of formal schooling, and many studies have demonstrated the effects of schooling on cognitive skills (Greenfield, 1966; Laboratory of Comparative Human Cognition, 1983; Rogoff, 1981). The effects of nutrition may be modified by differences in school experiences. In the food-supplementation study reported by Chavez and Martinez (1981), differences between supplemented and nonsupplemented children diminished in the second year of schooling, which the authors attributed to the poor quality of education. Thus, the association between the duration of schooling and cognitive skills is important to investigate.

The aim of this research report was to examine the relations between attentional and cognitive skills of children in a developing country and nutritional status, family characteristics, and duration of school experiences. The focus of the nutritional measures was on energy intake. We hypothesized that the adequacy of the provisions available to the child in terms of food intake, educational resources of the family, and duration of school experience would be associated with the child's level of cognitive skills.

## Method

*Description of the Study Area*

The area of study includes three sublocations of Embu District, which is 120 miles northeast of Nairobi. The study area has been described in a previous paper (Sigman et al., 1988). Almost all individuals in the area belong to the Embu tribe and speak Kiembu. Most of the families in this area are monogamous and basically nuclear rather than extended; only monogamous families were included in this study. This community, with limited food resources and occasional droughts and food shortages, was selected rather than a more impoverished locale because of the intention to investigate the effects of mild to moderate undernutrition.

*Study Design*

Households were recruited into the study based on the presence or anticipated presence of a target individual. As mentioned in the introduction, target individuals consisted of pregnant women and their infants, toddlers, school-age children, and the parents of all these children. Food intake and anthropometry data were collected on these individuals. Some information, including indicators of social and economic status and sanitation, was collected for all 247 households involved in the study. Infants were followed from birth to 6 months of age and follow-up testing was administered at 30 months. Assessments and home observations of toddlers were carried out from 15 to 30 months, with a longitudinal follow-up at age 5 years. School-age children were followed over the course of a year.

*Sample*

The school-age sample consisted of 138 children, 62 females and 76 males. During the time of participation in the study, the children had a mean age of 7-7 (SD = 4-2), with a range from 7-1 to 8-5. Cognitive tests were administered to 133 children, 60 females and 73 males, on three occasions from June 1984 to May 1985. Classroom observations were carried out for 124 children, five of whom did not have cognitive assessments.

*Procedures*

*Cognitive assessments.*—Testing was carried out in the child's home with the child seated at a table or on the ground either in the house or outside. Testing was done by one of four women, very experienced with children, who lived in the area and were fluent in Kiembu and English. Training of testers was extensive and was carried out initially by one of the authors who observed each tester on multiple occasions. Subsequently, testing was supervised by a professional psychologist, Susan D'Souza, who observed more than half the test sessions. All testing was done in Kiembu.

The cognitive measures consisted of an assessment of verbal comprehension and an assessment of performance abilities. The verbal comprehension measure was similar to the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981) in that the child had to select the picture matching a verbal label from a set of four pictures. The test was designed in East Africa and used in urban settings in Kenya, Uganda, and Tanzania. For our purposes, the verbal labels were translated into Kiembu. The first two items were used to ensure that the child had understood the instructions; all children passed these items. The elementary items required picture recognition of simple nouns, whereas the most advanced items involved more abstract concepts. The Raven's Progressive Matrices (Raven, 1965) was used to assess performance abilities. This test required the child to select the correct pattern to complete a set of six patterns. At the level assessed in this study, the test required observation of perceptual detail and some awareness of sequence. All the items of both the verbal meaning and Raven's matrices assessments were administered because linear ordering of items according to task difficulty had never been established for this sample. The child's score was the total number correct on each test.

Because there were no standardization data available on these tests for this population, the means and standard deviations were computed for six age levels, each extending over 5 months. Raw scores were transformed into $z$ scores for each child on each test. Since the two measures were intercorrelated ($r$ = .49), a composite mean cognitive score has been used for analyses. There was stability in this cognitive score over time. Correlations from the first and second tests to the last test were significant, $r(124) = .68$, $p < .0001$, $r(129) = .71$, $p < .0001$, as were correlations from the first to the second test, $r(128) = .68$, $p < .0001$. Repeat reliability was similar for males and females. Construct validity was assessed using the mean school examination scores of children enrolled in school. The cognitive score was significantly associated with mean examination grades, $r(102) = .56$, $p < .0001$. Thus, the cognitive measures appeared to reflect some of the skills acquired and required in local schools.

Each child in this sample was tested three times with an interval of 2 months between the first two tests and 8 months between the second and third tests. In this article, the mean score obtained on the three tests was used for data analysis.

*Observations of classroom behavior.*—The children's behavior in the classroom was observed in order to determine the extent to which the children were able to attend to classroom activities. Observations were carried out by a group of people different from the groups assessing cognitive skills, nutritional intake, anthropometric status, and family characteristics. Using a time-sampling procedure (10 sec observe–20 sec record), observers coded whether the child talked to another child, played with an object, or was off task for the entire 10-sec interval. An observation session included three classes, each lasting from 25 to 30 min in length. Two children were coded alternately each 30-sec period during each class so that no single child was looked at continuously. The observations were conducted at 3-month intervals. Data were included only for children who were observed at least twice. The majority of subjects were observed on three different occasions, and some subjects were observed four times.

Interrater reliability was measured with observations of 18 children, each observed for three class periods. Correlations between observers for the various measures were high. For the measure focused on in this article, the number of intervals in which the child was totally inattentive, the interrater correlation was good, $r(17) = .93$, $p < .01$.

The data for each class and observation session were converted to percentage scores since the length of observation varied. Percentages were calculated for the number of intervals that the child engaged in an off-task behavior and the number of intervals in which no inattentive behavior occurred. Children were off task for 17% of the intervals on the first observation, 18% on the second observation, and 14% on the third observation. They were totally attentive for 66%, 67%, and 75% of the intervals during the three observation times, respectively. There was considerable intersession reliability in the extent to which an individual child was off task from one observation to the next. The correlations between percentages of off-task periods were $r(84) = .51$, $p < .0001$, from the first to the second observation and $r(97) = .44$, $p < .001$, from the second to the third observation. Stability was similar for males and females. Children who were off task frequently had lower cognitive scores, $r(117) = -.24$, $p < .05$, and lower school examination grades, $r(102) = -.23$, $p < .05$.

*Nutritional measures.*—Food intake was assessed for each child on 2 successive days monthly by a trained observer who watched cooking, measured volume and weight of recipe ingredients, and weighed food given to the child during the period from 7:00 A.M. to 6:00 P.M.. The mother was interviewed on the subsequent morning about food given to the child after 6:00 P.M., and the child was asked about food eaten out of the home. Both males and females were observed for just over a year ($M = 1.1$ years, $SD = .32$).

Conversion of the food to nutrient composition involved development of a nutrient data base, calculation of the nutrient values of household recipes, determination of nutrient values for standard recipes, and calculation of nutrient intake totals for individuals. Since no single food table appropriate for Kenya existed, 45 Kenyan foods, including staples and main dishes, were analyzed in a commercial laboratory in the United States. Other nutrient information came from a variety of sources, including the FAO tables for Africa and USDA tables. Standard recipes were collected for recall of dishes eaten away from home.

For this article, the school child's average consumption of calories, protein, carbohydrate, fat, and animal protein over the length of their involvement in the project was examined. These variables were selected because of the focus of the study on energy. Protein, carbohydrates, and fat are the main sources of energy in the diet. Animal protein is of particular interest because it is so scarce.

*Measures of physical development.*—Anthropometric measures were made monthly by pairs of trained local people who each made independent readings that they then corroborated. If the differences between readings exceeded certain limits, the children were remeasured. Height was measured with a portable device (nivotoise) consisting of a metal foot plate, a head plate, and a retractable steel tape. The headpiece has a built-in carpenter's bubble which when leveled indicates that the headpiece is horizontal. After selecting a measurement site with a hard, flat ground surface next to a vertical wall, the subject was asked to remove all footwear and to stand on the nivotoise foot plate with feet together. The subject was instructed to stand comfortably upright, with eyes looking ahead

and arms held loosely at the sides of the body. With the bottom end of the tape attached to the foot plate, the headpiece was raised (thereby extending the tape) and placed on the top of the head. By checking the bubble level, the enumerator verified that the headpiece was horizontal. Finally, after the body position and the position of the headpiece were checked by the partner, the tape was locked and a reading was taken by the first tester to the nearest 0.1 cm and recorded on the form. The second team member then repeated the procedure. Portable, battery-powered, digital read-out Heath scales were used to weigh the children. While the tester zeroed the scale, the child removed as much excess clothing as possible, bearing in mind the constraints of privacy and warmth. The child was then instructed to stand perfectly still with both feet together on the middle of the scale and facing the display. Upon steadying, the displayed weight was read by the first tester to the nearest 0.1 kg and recorded on the form. The procedure was then repeated by the second tester. The Heath scale was calibrated regularly and yielded comparable values to a beam balance. Repeat measurements were done on the same or next day for 30 children, with good reliability, $r(28) = .96$ for height, .99 for weight, $p < .001$. While a variety of anthropometric data were collected, only the mean height for age, weight for age, and weight for height that the children attained over the period of observation are discussed in this article. Weight for height was correlated with the mean caloric intake, $r(136) = .55$, $p < .001$, supporting the validity of the food intake and anthropometric measures.

*Family characteristics.*—Family demographics were characterized by the overall socioeconomic standing and the literacy of the parents. Socioeconomic status was measured with a scale that rated the amount of land and material objects possessed by the family, the quality of the homestead, and outside income. Interviews were conducted quarterly during the time that the family was enrolled in the study. Revisits within 1 week of the original interview were conducted for 3% of the sample, and the data obtained corresponded exactly for 84% of the values. In order to validate this scale, the local subchiefs developed criteria to distinguish between households that were more or less esteemed and ranked households in their locales on this basis. The association between the subchiefs' rankings and the project socioeconomic status measure was fairly substantial, $r(245) = .48$, $p < .001$.

Parental literacy was assessed with measures of the ability to read and comprehend passages of text from graded local test books selected to reflect different levels of difficulty. Test score was equal to the total number of passages read aloud on which two of three questions were answered correctly. Twenty-nine adults were tested simultaneously by two examiners with perfect agreement on scoring.

*Duration of schooling.*—The child's school standard or grade was recorded by classroom observers who were present in the classroom in January 1985. Children were in nursery school or in first or second standard, although a few children were in the third standard. In this area not all children attend nursery school, but no child is placed in the second standard without having been in the first standard. The group was divided into two educational levels, nursery school and first standard ($n = 69$) and second and third standard ($n = 61$). At the time of the testing, the children in the first group had been enrolled in school for a half year to 1½ years, while the children in the second group had been enrolled in school for 1½ to 3 years. There were no school data available for eight children.

## Results

### *Physical Stature*

The mean height for the male schoolchildren in this sample was 116.24 cm (SD = 5.0) and mean weight was 20.15 kg (SD = 2.1). For the females, mean height was 115.54 cm (SD = 6.6) and mean weight was 19.88 kg (SD = 2.9). Using reference data provided by the National Center for Health Statistics (Hamill et al., 1979), about 25% of the sample were considered stunted in that their heights for age were less than 90% of the median. For the whole sample, the mean $z$ score for height calculating scores with NCHS standards was −1.69 (SD = 1.03) with a range from −4.44 to +0.71. Only nine children had $z$ scores above 0. The mean $z$ score for weight for age was −1.46 (SD = .81) with a range from −3.76 to +.50, with only five $z$ scores above 0. Only about 1% of the sample had weights for age that were less than 60% of the median, but 40% had weights for age that were between 60% and 80% of the median. The mean $z$ score for weight for height was −.47 (SD = .68), with a range from −2.47 to .95 and 33 $z$ scores above 0. Thus, these children were quite small and thin by comparison with the NCHS data, with mean weights and heights around the fifth percentile. The justification

TABLE 1

MEANS OF MALE AND FEMALE CHILDREN

| | FEMALES (62) | | MALES (76) | |
|---|---|---|---|---|
| | *M* | SD | *M* | SD |
| Physical measures:[a] | | | | |
| Height for age | −1.73 | 1.16 | −1.67 | .92 |
| Weight for age | −1.52 | .91 | −1.42 | .72 |
| Weight for height | −.53 | .72 | −.43 | .64 |
| Food intake: | | | | |
| kcal[b] | 1,361.70 | 221.84 | 1,523.89 | 248.30 |
| Protein (g/day)[b] | 39.95 | 7.32 | 45.08 | 8.20 |
| Animal protein (g/day) | 2.56 | 1.19 | 2.78 | 2.17 |
| Fat (g/day)[b] | 20.18 | 5.18 | 22.34 | 5.54 |
| Carbohydrates (g/day)[b] | 269.71 | 43.22 | 301.76 | 48.25 |
| Family factors: | | | | |
| SES | 90.83 | 18.50 | 88.55 | 15.51 |
| Paternal literacy | 6.80 | 4.13 | 6.93 | 4.59 |
| Maternal literacy | 4.50 | 4.24 | 4.23 | 3.81 |
| Cognitive scores: | | | | |
| School examinations | 133.10 | 56.69 | 117.29 | 48.62 |
| Cognitive *z* score | .20 | 1.44 | −.10 | 1.51 |

[a] Physical measures reported as *z* score transformations using NCHS standards.
[b] Significantly different for males and females, $p < .05$.

for using NCHS data as a comparison is that Kenyan urban middle-class and wealthy children, as well as children of wealthy rural families, are at or above NCHS median values (Stephenson, Latham, & Jansen, 1983). The males and females in the sample were not different in terms of their weight for age or height for age (see Table 1).

*Food Intake*

The mean daily energy intake for the male schoolchildren was 1,524 kcal, with a range from 995 to 2,240 kcal. For the females, mean intake was 1,362 kcal, with a range from 876 to 1,902 kcal. In order to estimate energy requirements for this sample, a report by the FAO/WHO/UNU (1985) was used. Using group mean weights, predicted basal metabolic rates, and estimates of moderate activity level, male schoolchildren in Embu are thought to require 1,626 calories daily, while females are thought to require 1,464 calories daily. With these estimates, the overall sample received 93%–94% of the FAO recommended intake. Sixty-five percent of the boys and 73% of the girls had daily caloric intakes below the recommended levels.

The mean daily protein intake for the males was 45 grams, with a range from 28 to 69 grams, while the mean for the females was 40 grams, with a range from 25 to 57 grams. Only about 6% of this protein came from animal sources. The mean daily intake of animal protein was 2.7 grams, with a range for 0 to 10 grams. Based on the FAO/WHO/UNU estimates of the amount of egg and milk protein required to sustain normative levels of protein accretion in normal children, Embu schoolchildren are thought to require a mean of .81 grams per kilogram of body weight daily. Given a mean weight of about 20 kg for the children in this sample, the daily intake of protein was about 1.99 grams per kilogram for the females and 2.23 grams per kilogram for the males. However, over 90% of the protein came from vegetable sources.

Aside from the fact that caloric intake was low for 65%–70% of the children in the sample, there are other reasons for concluding that the children were not adequately nourished. First, estimates of dietary requirements are based on weight, and these children were very small and thin, so the estimates were necessarily very low. Second, these estimates assume moderate activity levels, but some children in Kenya appear to be very active. Finally, there was variability within the sample, so a sizable proportion of children had energy intakes far below the recommended levels.

As expected, the levels of the various nutrients were intercorrelated. Overall mean energy intake, carbohydrate intake, and protein intake were all very highly correlated ($r$'s > .90). Correlations between the level of fat in-

TABLE 2

CORRELATIONS BETWEEN COGNITIVE SCORES, ANTHROPOMORPHIC MEASURES, FOOD INTAKE, AND FAMILY CHARACTERISTICS

| | FEMALES ($n$ = 60) | | MALES ($n$ = 73) | |
|---|---|---|---|---|
| | Cognitive Scores | Classroom Behavior | Cognitive Scores | Classroom Behavior |
| Physical measures: | | | | |
| Height for age | .35* | −.14 | .21 | .02 |
| Weight for age | .48* | −.07 | .36* | .07 |
| Weight for height | .47* | −.02 | .37* | .08 |
| Food intake: | | | | |
| kcal | .43* | −.27* | .28* | .04 |
| Protein | .46* | −.28* | .28* | .02 |
| Animal protein | .51* | −.26* | .53* | −.03 |
| Fat | .60* | −.28* | .48* | .01 |
| Carbohydrates | .31* | −.23 | .19 | .05 |
| Family factors: | | | | |
| SES | .56* | −.22 | .55* | −.19 |
| Paternal literacy | .42* | −.20 | .47* | −.13 |
| Exam grades[a] | .62* | −.26 | .59* | −.24 |

[a] n's are slightly lower because of some missing data.
* $p < .05$.

take and the other nutrients were somewhat lower but still robust ($r$'s ranged from .59 to .78). The level of intake of animal protein was highly significantly related to fat intake ($r$ = .78), moderately related to protein and overall energy consumption ($r$'s = .36 and .32) and uncorrelated with carbohydrate consumption. The correlations between nutrients were almost identical for males and females.

The gender differences in food intake were significant, Hotelling-Lawley $F(5,132) = 3.26$, $p < .01$. The males had significantly higher calorie, protein, fat, and carbohydrate intakes than the females, but the two groups did not differ in animal protein intake (see Table 1). Given the differences in food intake, subsequent analyses were calculated separately for males and females.

### *Relations between Cognitive Scores and Nutritional Status*

In order to determine if nutritional status was associated with cognitive abilities, Pearson product-moment correlations were computed between the score on the cognitive assessments with the three anthropometric and five food intake measures. All the anthropometric and food intake measures were positively associated with cognitive scores except for height and carbohydrate intakes for the boys (see Table 2). While the relations between food intake and cognitive score seemed stronger for the females than the males, the correlations were not significantly different, and this was also true for the correlations between food intake and classroom behavior reported below.

In order to determine if the effects of caloric intake were similar across the whole range, the children were divided into three groups based on their caloric intake. This division was done separately for males and females because of the differences in their food intake. The cognitive scores of the children in the three groups differed significantly, $F(2,130) = 9.37$, $p < .002$. According to post-hoc comparisons, the cognitive scores of the children whose intake was in the bottom third of the distribution differed from the cognitive scores of the children in the other two groups. The cognitive scores of the children whose caloric intake was intermediate did not differ from the scores of the children with the highest caloric intake. Thus, some minimal level of caloric intake was necessary for adequate functional development.

### *Relations between Cognitive Scores and Family Characteristics*

Pearson product-moment correlations were computed between the measures of parental literacy and SES with cognitive scores. A mean reading score for both parents was computed from maternal and paternal reading scores. The socioeconomic and educational resources of the family were associated with cognitive scores for both girls and boys (see Table 2). Children with more literate parents

TABLE 3

CORRELATIONS BETWEEN SES AND FOOD INTAKE

| | Females | Males |
|---|---|---|
| kcal | .22 | .32* |
| Protein | .23 | .30* |
| Animal protein | .56* | .52* |
| Fat | .49* | .52* |
| Carbohydrates | .09 | .23* |

* $p < .05$.

from families with more resources had higher scores on both cognitive measures.

*Relations between Food Intake and Family Characteristics*

One would expect that children raised in families with more economic and educational resources would be better nourished, and this was generally true. All the food intake variables, except carbohydrates, were associated significantly with SES when the sample was pooled. More of the correlations were significant for the males than the females (see Table 3), although there were no significant differences in the size of correlations between the two sexes. SES was most highly correlated with intakes of fat and animal protein. In other words, families with better economic and educational resources also provided their children with better nutrition.

Given that food intake and SES were correlated and both were associated with cognitive scores, the relative contribution of each is of interest. When SES was forced into the regressions with cognitive scores, all the food intake remained significantly associated with cognitive scores for the females (see Table 4). However, only fat and animal protein intakes were significantly correlated with cognitive score when SES was covaried for the males. The covaried correlations were not significantly different for the males and females, so the correlations were computed for the sample as a whole. All the food intake variables were associated with cognitive score except level of carbohydrates when SES was covaried for the whole sample. SES continued to be correlated with the cognitive scores for males and females even when food intakes were forced into the equation first.

The correlations for fat and animal protein are larger than for the other food intake measures. Fat intake was significantly more highly related to cognitive score than carbohydrate intake, $t(130) = 2.38$, $p < .05$, and overall energy intake, $t(130) = 2.20$, $p < .05$.

*Classroom Behavior*

One of the important questions raised in this project was whether insufficient nutritional intake was associated not only with more limited cognitive abilities but also with distractibility and poorer ability to concentrate on classroom lessons. To address this question, Pearson product-moment correlations were calculated between the mean of off-task behaviors over all observations and measures of food intake. There were no significant associations between percentage of time that the child was off task in the classroom and food intake for the males, but there were significant associations for the females. Girls with higher calorie, fat, protein, and animal protein intake levels were off task less than girls with lower levels of food intake (see Table 2). Thus, well-nourished females were more attentive in class, while malnourished females more frequently engaged in off-task behaviors.

*Duration of Schooling*

In order to compare differences as a function of duration of schooling, cognitive scores for children in the higher grades were compared with cognitive scores for children in the lower grades. As hypothesized, children with

TABLE 4

CORRELATION BETWEEN COGNITIVE SCORE AND FOOD INTAKE WITH SES COVARIED

| | Females ($n$ = 60) | Males ($n$ = 73) | All ($n$ = 133) |
|---|---|---|---|
| kcal | .37* | .12 | .18* |
| Protein | .39* | .15 | .21* |
| Animal protein | .29* | .34* | .31* |
| Fat | .44* | .27* | .31* |
| Carbohydrate | .30* | .07 | .13 |
| SES (when food intake covaried) | .34* | .37* | .38* |

* $p \leq .05$.

TABLE 5

MEANS OF CHILDREN WHO VARIED IN LENGTH OF SCHOOLING

| | LESS SCHOOL ($n$ = 69) | | MORE SCHOOL ($n$ = 61) | |
|---|---|---|---|---|
| | $M$ | SD | $M$ | SD |
| Physical measures:[a] | | | | |
| Height for age | −1.90 | .98 | −1.42 | 1.00 |
| Weight for age[b] | −1.61 | .72 | −2.24 | .78 |
| Weight for height[b] | −.49 | .68 | −.39 | .63 |
| Food intake: | | | | |
| kcal (g/day)[b] | 1,41[illegible].82 | 244.91 | 1,512.71 | 232.62 |
| Protein (g/day)[b] | 41.46 | 8.27 | 44.85 | 7.45 |
| Animal protein (g/day)[b] | 2.13 | 1.34 | 3.38 | 2.54 |
| Fat (g/day)[b] | 19.96 | 4.67 | 23.48 | 5.67 |
| Carbohydrates (g/day) | 283.31 | 47.2[illegible] | 295.88 | 46.81 |
| Family factors: | | | | |
| SES[b] | 85.13 | 14.21 | 97.33 | 16.36 |
| Paternal literacy[b] | 5.83 | 4.26 | 8.21 | 4.20 |
| Maternal literacy[b] | 3.40 | 3.58 | 5.81 | 4.21 |
| Cognitive score[b] | −.68 | 1.10 | 1.10 | 1.33 |

[a] Physical measures reported as z score transformations using NCHS standards.
[b] Significantly different for school groups, $p < .05$.

longer durations of schooling had higher cognitive scores, $t(122) = 7.75$, $p < .001$. This did not seem attributable to selective promotion policies since the same effects were present when only the data for children promoted within the year were analyzed. The correlation between the duration of schooling and cognitive score was significant when age was covaried, $r(121) = .60$, $p < .001$. However, the children with more schooling came from more prosperous families and were provided with more food according to three Hotelling's $t$ tests calculated on the differences in food intake, physical stature, and family characteristics. Except for height and carbohydrates, comparisons of the individual variables were also significant (see Table 5).

To determine whether duration of schooling contributed to cognitive scores regardless of age, physical stature, level of food intake, and family characteristics, a stepwise regression was calculated with the cognitive score as a dependent measure. The independent variables consisted of the anthropometric, food intake, and family variables as well as the duration of schooling and mean age. Duration of schooling, mean intake of animal protein, weight for age, and SES entered into the regression, accounting for 54% of the variance (see Table 6). Thus, the extent of school participation had an effect on cognitive abilities independent of the child's family background and nutritional status. This analysis also indicated that a variety of factors including school experience, family economic resources, and nutritional adequacy all influenced the cognitive skills of these children in rural Kenya.

## Discussion

Food intake was clearly related to the cognitive skills of these Kenyan schoolchildren. Regardless of the social and economic resources of the family, children who had

TABLE 6

MULTIPLE REGRESSION BETWEEN NUTRITIONAL MEASURES, FAMILY CHARACTERISTICS, AND DURATION OF SCHOOLING WITH COGNITIVE SCORES

| Variable | $R^2$ Added | $F$ | $p$ |
|---|---|---|---|
| Duration of schooling | .33 | 89.93 | .001 |
| Animal protein | .13 | 36.33 | .001 |
| Weight for age | .05 | 13.87 | .001 |
| SES | .03 | 9.49 | .003 |
| Total $R^2$ | .54 | ... | ... |

more adequate diets had higher scores on the cognitive battery than children with less adequate diets. These results are similar to our findings with the toddlers in this project (Sigman, Neumann, Baksh, Bwibo, & McDonald, in press) and with the toddlers in the Egyptian project (Wachs et al., 1988). Better-fed toddlers were more verbal, played more in the home setting, and showed more sophisticated play at 30 months than toddlers with less adequate diets. Moreover, fat and animal protein intakes between 18 to 30 months were related to scores on the cognitive battery described in this article which was administered in the Kenyan project to children at 5 years of age (Sigman, McDonald, Neumann, & Bwibo, 1989).

One of the important questions is the role of present nutrition in contrast to nutritional history. The fact that food intake at an earlier period is also related to cognitive scores suggests that the relation between food intake and performance in this sample of school-age children may reflect a process that has earlier roots. Considering their height and weight, at least some of the children in this sample may have had inadequate nutrition for most of their lives. Moreover, families appear to furnish similar levels of nutrition to children of different ages. For the 41 families with both a toddler and a schoolchild, energy intakes for the two children were correlated regardless of SES, $r(39) = .61$, $p < .01$.

The only counterevidence is the insignificant relation between height and cognitive score for the males since height is often used as an index of nutritional history. However, this cannot be considered too strongly since the correlations for males and females were not significantly different, and height was correlated for the sample as a whole. Furthermore, we have found for our younger sample that length at 30 months was associated with cognitive score at 5 years. Finally, the differentiation of weight and height as indices of present and past nutrition seems less useful in this sample where height continues to be affected by current nutrition.

While all the food intake variables were associated with cognitive scores, fat intake appeared to be more important than carbohydrate intake and overall energy intake. Fat may be important because it is a dense source of energy so that small differences have a large impact. Levels of animal protein were minimally associated with the other variables except fat, suggesting that animal protein added something to the diet, other than energy. Although the possibility of essential amino acid deficiencies cannot be ruled out, it is more likely that animal protein (and perhaps fat as well) is serving as a marker of diets that contain adequate levels of associated micronutrients such as iron, zinc, and vitamin B12. This is an area that needs more investigation.

One of the important issues is the path through which undernourishment influences learning and cognitive development. One hypothesis is that chronic hunger may interfere with the child's capacity to attend and learn. Children who were marasmic in the first year of life have been reported to show increased attention problems during the school year in contrast to children with no history of malnutrition (Galler, Ramsey, Solimano, & Lowell, 1983). Moreover, food supplementation appears to have had the most sustained effect on social-emotional development rather than cognitive development (Barrett et al., 1982). In order to address this issue, attentional behavior in the classroom was observed. Well-nourished female schoolchildren were more attentive to classroom tasks than undernourished female schoolchildren. Thus, some girls may simply be too hungry to focus on school tasks, and this may interfere with their learning.

One of the major limitations in most studies relating nutrition to behavior has been the confounding of nutritional and environmental factors. This study attempted to deal with this issue by separating the effects of nutritional factors from family characteristics, such as SES and parental literacy. The results showed that both nutritional factors and family resources were important for the children's cognitive scores. However, family economic, social, and educational resources are distal influences on the child, not proximal influences, like family teaching or social interaction patterns. We decided not to observe home interaction patterns because, in pilot work, the school-age children appeared to spend their time out of school with peers and siblings, often wandering over large areas. In addition, they were very self-conscious about being observed in their family settings. Home observations were carried out with the toddlers, and caregiver behaviors were related to the children's cognitive and verbal skills (Sigman et al., 1988), as was true in the Egyptian study (Wachs et al., 1988). However, food intake appeared to influence cognitive development of the Kenyan toddlers independently

of the effects of the home environment (Sigman et al., in press).

Participation in school also seemed important for the kinds of cognitive skills measured in this study. Children who had attended school longer were from wealthier, better-educated families, as reported in other studies (Jamieson, 1986; Moock & Leslie, 1986), but schooling was important regardless of family background. It is possible that families chose to send more verbally competent children to school at earlier ages. Furthermore, schooling may make the children more familiar with the matching task and kinds of representations used in the verbal meaning test. Formal schooling is clearly not the only means for children to develop cognitive abilities in that children learn skills through other economic and social activities (e.g., Saxe, Guberman, & Gearhart, 1987). However, schooling did appear to moderate the effects of nutrition on cognitive abilities.

The strength of this school-duration measure is surprising for several reasons. First, duration would appear to be a rather insensitive measure, and one would prefer to know something about the quality of the educational experience. Second, in many less developed countries, children may be enrolled in a particular grade but may not attend school consistently because they do not have school fees or are needed at home. For this reason, a measure of school attendance would be very useful. Unfortunately, our measure of school attendance is less complete than would be hoped. However, when the same analyses were conducted with the school attendance data available, similar results were obtained.

There is a strong emphasis on school learning in Kenya at present. Because of the limited amount of arable land and very high birth rate (Kaplan, 1984), increasing numbers of people will have to earn their livelihoods in occupations other than farming. Parents, teachers, and national leaders aim to foster the kinds of cognitive abilities taught in schools in order to prepare children for alternative employment. This study aimed to identify the kinds of environmental factors associated with such cognitive abilities. The results showed that all the factors studied—nutritional intakes, school participation, and family characteristics—were relevant. Well-fed children from more educated families who participated for longer periods in school were more skillful than undernourished children with less school experience from less educated families. Based on these findings, one would recommend interventions for promoting cognitive function that used a multifactorial approach.

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APPENDIX F

# Home Interactions and the Development of Embu Toddlers in Kenya

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SIGMAN, MARIAN; NEUMANN, CHARLOTTE; CARTER, ERIC; CATTLE, DOROTHY J.; D'SOUZA, SUSAN; and BWIBO, NIMROD. *Home Interactions and the Development of Embu Toddlers in Kenya.* CHILD DEVELOPMENT, 1988, 59, 1251–1261. The social interactions experienced by 110 Embu children growing up in a rural Kenyan community were observed bimonthly when the children were between 15 and 30 months of age. Children who were talked to frequently, whose vocalizations were responded to, and who engaged in sustained social interactions passed more of the items on a revised version of the Bayley Mental Scale at 24 and 30 months of age and showed more positive affect than children who had been less involved in verbal and social interactions during the previous home observations. Children who were carried a great deal between 15 and 30 months of age scored poorly on both Bayley Mental and Motor Scales at 30 months of age. Social and verbal interactions were associated with developmental scores regardless of the child's initial verbal ability. The level of paternal literacy was associated with the cognitive development of these Kenyan toddlers at 30 months of age, and social interactions accounted for some of the variability in development beyond this association.

The purpose of this research is to describe the rearing conditions and patterns of development of a group of toddlers growing up in rural Kenya and to examine the associations between rearing conditions and development. Numerous studies have documented the associations between characteristics of the home environment and the child's level of development in the United States. However, the extent to which these findings pertain to child rearing and development in other cultures is still largely unknown.

Anthropologists and cross-cultural psychologists have stressed the importance of cultural context in shaping both child-rearing conditions and the development of children (LeVine & White, 1986; Super & Harkness, 1980). LeVine (1977) has pointed out that, in areas of high infant mortality, child-rearing practices may be concerned with promoting infant survival rather than the development of competence. For this reason, there may be much less time invested in talking to infants and interacting with them in face-to-face situations, and they may be carried on the back of an adult or sibling to protect them from dangerous physical situations. In addition, the definitions of competence may vary so that parents may have different aims for their children (Lutz & LeVine, 1983). As an example, children in Uganda are expected to be very interactive, and so parents encourage smiling, and sociability items on the Bayley scales show an early emergence (Kilbride & Kilbride, 1974). Thus, caregiving may differ substantially in rural Kenya so that associations between rearing conditions and development observed in the United States and western Europe may not be identified in this sample.

In Western countries, the home environment is associated with cognitive development beginning in the second year of the infant's life (Gottfried, 1984; McCall, 1979; Wachs & Gruen, 1982). While some studies

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report significant associations between the social environment in the first year of the infant's life and later development (Barnard, Bee, & Hammond, 1984; Beckwith & Cohen, 1984; Bornstein, 1985; Bradley & Caldwell, 1984), the associations seem more robust in the second year (Burchinal & Farran, 1980; Clarke-Stewart, 1973; Field et al., 1978; Olson, Bates, & Bayles, 1984; Ramey, Farran, & Campbell, 1979). Even where development does seem to vary with early home environment, the effects often can be attributed to environmental characteristics existing in the child's second and third years of life, which have remained stable from the first year. For this reason, we have chosen to investigate relations between home environments and the development of toddlers between 15 and 30 months of age.

The nature and specificity of the important social variables have not been fully determined. Certain rearing characteristics seem to be important across a broad age span, while others are relevant only at particular points in development (Wachs & Gruen, 1982). The extent of maternal involvement, the degree of variation in stimulation, and the verbal environment provided by caregivers and siblings seem meaningfully related to children's cognitive development across the early years of life. On the other hand, physical contact and responsiveness to distress seem most significant early in infancy, while responsiveness to the child's vocalization necessarily becomes influential somewhat later (Bakeman & Brown, 1980; Stevenson & Lamb, 1979). Sustained social interactions with older siblings and peers can only affect the child at ages when these are common. The question of specificity of effects is still at issue. Home characteristics may affect development generally or may only influence the acquisition of particular skills and characteristics (Heinicke, Diskin, Ramsey-Klee, & Oates, 1986; Wachs, 1984).

Characteristics of the home environment may appear to affect the child's development when, in actuality, associations may be due to the stability of particular traits in the child. For example, a child with strong verbal skills may engage his or her family in more dialogue so that the family shows high frequencies of verbal behavior during home observations. If these early verbal skills in the child continue over time, associations between the verbal environment and the child's subsequent verbal development may have more to do with the child's level of verbal skill when first measured than any environmental effect. In some studies, home variables entered into regressions even after initial developmental quotients were considered (Olson et al., 1984; Siegel, 1984), while in another study, the home measures did not add much to the Bayley Mental Developmental Index at 24 months beyond the contribution of the Bayley Mental Developmental Index at 12 months (Johnson, Breckenridge, & MacGowan, 1984). The present study addresses this issue by identifying continuities in the child's development and examining the effects of the home environment independently of these continuities.

The final aim of this study is to compare the effects of the social environment with more distal influences on the child's development. In most studies that have evaluated proximal and distal measures, both rearing conditions and socioeconomic settings have been associated with the children's development (Gottfried & Gottfried, 1986). The independence of rearing conditions from other more genetically loaded distal measures, such as intelligence and educational level of parents, is less clear. The major question is whether the social rearing variables are important in themselves as critical process variables or are just markers for other more important variables. Rearing factors have been identified that contribute to the child's cognitive development independently of maternal education and intelligence (Barnard et al., 1984; Gottfried & Gottfried, 1984; Plomin & DeFries, 1985). In this study, parental literacy will be examined to measure the educational attainments of the parents. The extent to which home interactions affect the child's development given the family's educational level will be measured. In this way, the contribution of the more immediate social environment and of the broader social milieu can be contrasted.

The community selected for study is in Eastern Province, Kenya, in a rural area northeast of the town of Embu. While other studies have investigated the relations between caregiving and infant cognitive development in African infants (Goldberg, 1977; Harkness & Super, 1982; Kilbride & Kilbride, 1974; Leiderman & Leiderman, 1974; Munroe & Munroe, 1984), no other studies have been carried out with this tribe, this community, or this age group.

## Method

### *Description of the Study Area*

The area of study includes three sublocations of Embu District, which is 120 miles

northeast of Nairobi. The total area is about 60 $km^2$ and is about 30 km northeast of the town of Embu. The study area is on the slopes of Mt. Kenya, the elevation ranging from 1,200 to 1,460 m. Homesteads, called *shambas*, are scattered and are usually near or adjacent to their fields. The buildings are constructed primarily of mud with wood frames and occasionally of stone or bricks. The roofs are of thatch, with the better houses having tin roofs. There is no electricity, and a gravity-fed, piped water system reaches only some of the homesteads. Embu district is an area of mixed agriculture with mostly subsistence agriculture and some cash crops. There are about 1,600 households in the three sublocations, and the average household includes about six to seven people per household. Almost all individuals in the area belong to the Embu tribe and speak Kiembu. Most of the families in this area are monogamous and basically nuclear rather than extended; only monogamous families were included in this study.

Families depend mostly on their own food production to feed themselves, and both mothers and fathers spend about 15% of their day cultivating crops or caring for animals. Fathers spend about a third of their time involved in labor for which they are paid. Mothers are involved in daily household chores for more than half their time. Fields are located adjacent to dwellings, so mothers are likely to bring toddlers with them or have them in view. When toddlers are left behind, they are usually with a group of children, including older sisters. Children attend school during the morning hours and return home around noon so older siblings, relatives, and neighbors are available to interact with toddlers during most of the day.

*Sample*

The sample was collected by identifying and enrolling households with children between 15 and 18 months of age. Home observations began when the child was enrolled in the project, the first cognitive testing was administered at 18 months of age, and the child was followed until 30 months of age. While 115 toddlers were observed in their homes, four toddlers were seen only once, so their data were not included. The 18-month cognitive tests were administered to 110 toddlers, 52 males and 58 females. Two females were never tested again; one male and one female were not tested at 24 months but were tested at 30 months; and three males were seen again at 24 months but not tested at 30 months. Four of the five children not tested at 30 months were in families that dropped out of the study. Hearing and vision were assessed, and there were no toddlers with major auditory or visual impairments.

*Procedures*

*Home observations.*—Observations in the home were made for two different purposes. One aim of the home observations was to describe the home-rearing conditions in terms of the toddlers' experiences and their interactive partners. The second purpose was to assess types of behaviors that could not be measured in a structured testing situation. These included such behaviors as the frequency of vocalizing, playing with objects, crying, smiling, and laughing. Observations were made during daylight hours for reasons of safety and were alternated between mornings and afternoons. Observations were made 6 days a week and were carried out if the toddler was present and visible. Mothers were not requested to be at home but usually were present, as can be seen from the data described below.

The observational procedures took nearly 18 months to design. In the first 6–9 months of the project, the aim was to measure all activities of all individuals being studied in each household. We began, therefore, by recording all activities observed of the pilot subjects. When the focus changed to the rearing of the toddler, the activities were restricted to those concerned with the toddler. A large number of activities were observed using a continuous recording technique. However, the observers, who were local young adults, felt that their observations were inaccurate. For this reason, we developed two different observational systems, one concentrating on caretaking and protective behaviors and the other concentrating on verbal and interactive behaviors. The use of the two observational systems was alternated monthly. For the second observational system, described in this article, a very restricted group of variables were chosen from the larger list, with preference given to those behaviors that had been observed in previous Western and African studies.

In order to increase observer accuracy and reliability, a time-sampling method was used in which the observer noted any behavioral category that occurred in a 30-sec interval. The following 30 sec were used for recording of data. Observations were done for periods of 120 min. If 120 min of data were not collected, the observer returned to the home to collect the data remaining. We have only used in analyses those records in which

at least 90 min of data are available and have limited each observation to 120 min. Percentage scores have been used throughout because of variations in the number of observation intervals.

Observations were carried out every other month so that each toddler was observed six to eight times. The data have been analyzed in two ways, either as means over all observations or as means within age periods. In the latter case, we have grouped the data collected when the toddlers were 15–30 months of age into five age periods, each period covering a 3-month span. The number of children observed in each age period varies, so that 63 children were observed between 15 and 18 months of age, 102 between 18 and 21 months, 111 between 21 and 24 months, 108 between 24 and 27 months, and 109 between 27 and 30 months.

The following social interaction and behavior patterns were coded: physical care, holds or carries, touches, social interaction, and talks to the child (see Table 1 for definitions). The following toddler behaviors were coded: vocalizes, cries or whines, smiles or laughs, and plays with objects. None of the behaviors were mutually exclusive, so that any number could be coded in one time frame. For example, both physical care and talking would have been coded if a caregiver fed the child and talked to her or him simultaneously. Besides recording that a social interaction had occurred, the observer noted whether the other participant was any of the following individuals: mother, father, grandparent, any other adult, older sister, older brother, any other child, or more than one person. These were mutually exclusive, so that intervals in which several participants interacted separately but successively with the child were coded as "more than one person." When the toddler cried or vocalized, this was recorded, as well as whether a vocal, physical, or combined vocal-physical response was made. If the toddler were taken into the house or to some location where he or she could not be seen, the time period was coded as out of view. The observer stopped recording after the child had been out of view for 10 min.

TABLE 1

DEFINITIONS OF HOME-REARING VARIABLES

| |
|---|
| Physical care: any caregiving behavior such as feeding, washing, changing clothes, toileting, putting to sleep. |
| Hold/carry: holding in arms or on lap, picking up, or carrying so that the child's feet are off the ground or the child is not supporting her or his own weight. |
| Touch: coded when anyone touches any part of the child. An example is two children holding each other's arms. |
| Social interaction: child is actively involved in an ongoing social interchange with someone else or a group. Does not include the child watching others or toddler sitting with a group but not talking or playing. |
| Talks to toddler: individual talks directly to the child while looking at the child or holding the child and interacting. Does not include yelling at the toddler from afar. |
| Response to vocalization/distress: vocal physical response to toddler vocalization or cries within 5 sec. Responder must be close enough so toddler can hear and not be involved in conversation with others. Physical response includes patting or rocking the child or handing something to the child. |

In order to determine the reliability of the observational procedure, 17 toddlers were observed by 15 observers, working in pairs. Each pair of observers saw two toddlers, with each observational period lasting for 40 min. Data sheets were collected from the observers immediately after the observation period, and observers were urged to carry out observations independently. Interrater ageements were calculated with Pearson correlation coefficients and were uniformly high. For the interaction variables, the correlations were as follows: physical care, $r(15) = .98$, $p < .01$; carry, $r(15) = .98$, $p < .01$; touch, $r(15) = .85$, $p < .01$; talks to child, $r(15) = .90$, $p < .01$; and social interactions, $r(15) = .93$, $p < .01$. In terms of the responsiveness measures, the correlations were somewhat lower: any response to toddler vocalizes, $r(15) = .94$, $p < .01$; verbal response to toddler vocalizes, $r(15) = .94$, $p < .01$; any response to toddler cries, $r(15) = .69$, $p < .01$; verbal response to toddler cries, $r(15) = .80$, $p < .01$. For the toddler behaviors, the observers agreed to a remarkable degree: vocalizes, $r(15) = .89$, $p < .01$; cries, ($r = .96$), $p < .01$; smiles and laughs, $r(15) = .96$, $p < .01$; and plays with objects, $r(15) = .93$, $p < .01$. The high correlations are not surprising, as this group of observers had been practicing observational techniques with very complicated systems for about 9 months before learning this rather simple system.

*Cognitive assessments.*—Testing was carried out in the child's home with the child seated at a table either in the house or outside. Testing was done by one of four women

who lived in this area, were fluent in Kiembu and English, were very experienced with young children, and had not done the home observations. The major assessment tool was a modified form of the Bayley Scale. We chose this scale because it measures abilities, such as word and form recognition, that appear to develop in all cultures in the early years of life, although the particular language, perceptual, and motor usages may differ (Werner, 1979). Furthermore, the Bayley Scale has been used successfully by previous investigators in rural Kenya (Leiderman & Leiderman, 1974), and alternative measures have not been designed for toddlers in this area.

Alterations were made in the testing protocol and scoring. First, some modifications were made in the Bayley items so that the scale was more appropriate for the culture and testing conditions. At 18 months, only the verbal items of the Bayley Scale were used because the toddlers were very shy and testing required a long period of time. The pictures used for labeling and word recognition were taken from local picture books and were selected as appropriate by local people. The objects discriminated were changed from a cup, plate, and box to a cup, bowl, and can as plates and boxes are more rare than bowls and cans. The body parts of the doll that the child was to name were changed as well. This was necessary as the children were very reluctant to touch or look at the doll that was part of the Bayley kit. For this reason, local dolls, made of straw, were used, and these dolls did not have ears or very clear facial features. All the verbal items from no. 116 to the end of the test were assessed at 18 months, with the exception of the items requiring recognition of a watch from ambiguous drawings (nos. 145 and 150) because there are few watches and clocks visible in the environment. At 24 and 30 months, all the Bayley mental items were administered from no. 116 on except the watch-recognition items. One additional item (no. 113, says two words) was included at all ages.

For the purpose of this study, total number of items passed was calculated for each toddler. Scores were not converted into developmental quotients because the standardization did not seem appropriate for this sample. The total number of items passed was used rather than the highest item passed as the linear ordering of items was not the same for the Kenyan toddlers as for Western toddlers. To some extent, items considered to reflect advanced receptive language skills were passed more frequently than items considered to reflect simpler expressive language skills, possibly because of some reticence on tasks demanding verbal responses (see Harkness & Super, 1982).

The Bayley Motor Scale was also administered at 30 months of age. All items from the fifty-seventh to the end of the test were given, except that nine items requiring a walking board or stairs were omitted because there are no stairs and few single steps in the environment of these children.

All testing was done within 4 weeks of age at 24 and 30 months; there was a somewhat broader range of ages at 18 months. For this reason and because the examiners were more experienced by the time that the toddlers reached 24 months of age, we have focused on the 24- and 30-month assessments in this article, although the 18-month data appear reliable and informative.

In order to ensure that the administration and scoring of the measures was standard, two different types of reliability studies, concurrent interobserver and repeated intraobserver, were carried out. First, the responses of a number of toddlers were scored by two individuals, the tester and an observer. There was good agreement on interrater scoring on the total Bayley Scale. On the 24-month Bayley score, the two observers agreed perfectly on 16 of the 26 cases, disagreed by 1 point on six cases, and disagreed by 2 points on four cases. At 30 months, there was perfect agreement on 15 of the 16 cases, and a 2-point disagreement on one case using the Bayley Scale. On the Bayley Motor Scale, the two observers only differed by 1 point on two of the 16 toddlers assessed jointly. Interobserver agreement was somewhat lower at 18 months on the Bayley Verbal Scale but still adequate, with a correlation between observers of $r(30) = .88$, $p < .01$, with a sample of 32 toddlers. Reliability coefficients on the same Bayley Verbal items were $r(12) = .94$, $p < .01$, at 24 months, and $r(14) = .99$, $p < .01$, at 30 months. Repeat reliability was also calculated, with testing carried out by the same tester over a 2-week period. The correlations in Bayley Verbal scores over this period were $r(57) = .70$, $p < .01$, at 18 months, $r(10) = .95$, $p < .01$, at 24 months of age, and $r(7) = .82$, $p < .01$, for 30-month-olds.

*Parental literacy.*—The ability of the parents to read and write was assessed with a measure designed for this purpose. For the reading test, passages of text were selected from graded textbooks used in Kenya to

reflect different levels of difficulty. The adult read each passage aloud several times and then answered three reading comprehension questions. The respondent was given the choice to be tested in Kiembu or English. Success on a passage was defined as correctly answering two of the three questions. The test was discontinued when the subject failed two successive passages. Test score was equal to the total number of passages on which there was success. For the writing test, passages of increasing difficulty were dictated to the respondent. After the respondent had completed writing, the passage was reread so the parent could check for errors. Errors were defined as spelling errors, omission of words, and replacement of words. The test was scored in the same way as the reading test. Twenty-nine adults were tested by two examiners simultaneously, and there was perfect agreement on scoring.

## Results

*Description of the Rearing Conditions*

Patterns of care and changes over time were described using the following rearing variables: physical care, holding, touching, talking to, and social interaction.

The rearing variables were analyzed with 2 (sex) × 8 (caregiver) ANOVAs in order to determine whether males and females were treated differently and whether there were significant differences in the percentage of caregiving among individuals. The only significant effect of sex was that males were involved in slightly more intervals of sustained social interaction than females. There were no significant interaction effects.

The main effect of the caregiver factor was significant for all five rearing variables. The means are shown in Table 2 with the means for father, grandparent, and other adult combined since the individual means were so small. As can be seen, the mother and older sister were the predominant caregivers, carrying the toddlers, providing physical care, and talking to them more than any other individuals in the *shamba*. The only exception to this pattern was in sustained social interaction, which almost always occurred between the toddler and other children. The toddlers were talked to for fully 35%–40% of the intervals observed, with about half of this conversation coming from mother and older sister.

To evaluate changes in rearing patterns over age, linear regressions were calculated for each rearing variable over all observations during the 15-month period. The only significant changes with age were declines in the percentages of physical care, $r(494) = -.38$, $p < .001$, and carrying, $r(494) = -.43$, $p < .001$. Mothers provided physical care for 10% of the observation intervals for the youngest age group, 6% of the intervals for the 18–24-month-olds, and 4% of the intervals for the 24–30-month-olds. The decline in carrying and holding the toddlers was even sharper. Mothers and older sisters carried the 15–18-month-olds for 23% of the intervals, the next age group for 12%, and the oldest group for 6% of the intervals, with the mothers carrying the toddlers about twice as much as the older sisters at every age. There were no significant changes with age in the extent to which children were touched, talked to, or involved in social interactions.

*Toddler Behavior and Caregiver Responsiveness*

Toddlers played with objects for about 35% of the observation intervals, and the total amount of time engaged in play remained relatively constant over the year. Like other individuals in the *shamba*, the toddlers talked a fair amount—for about 22% of the intervals—and this increased somewhat with age, $r(494) = .17$, $p < .001$. They cried for only 7% of the intervals, and this decreased with age, $r(494) = -.27$, $p < .001$. They smiled for 17% of the intervals, and this increased with age, $r(494) = .22$, $p < .001$. There were no sex differ-

TABLE 2

DISTRIBUTION OF CAREGIVING BY DIFFERENT INDIVIDUALS (%)

| Caregivers | Physical Care | Hold or Carry | Touch | Social Interaction | Talk |
|---|---|---|---|---|---|
| Mother | 5.2 | 7.3 | 3.0 | <1 | 10.8 |
| Other adults | 1.1 | 1.1 | 1.2 | <1 | 5.7 |
| Older sister | 1.8 | 3.4 | 3.5 | 1.6 | 9.7 |
| Older brother | <1 | <1 | 2.0 | 1.3 | 5.5 |
| Other child | <1 | <1 | <1 | 1.9 | 2.7 |
| More than one individual | <1 | <1 | 1.0 | <1 | 2.6 |

ences in these behaviors, and males and females changed with age in the same way. Responsiveness to the vocalizations and cries of toddlers were analyzed with 2 (sex) × 3 (type of response) ANOVAs, and there were significant effects in type of response but no sex differences. The majority of caregiver responses to toddler vocalizations and cries were vocal responses rather than physical or combined vocal-physical responses.

*Cognitive Performance*

Two factor (age × sex) repeated-measures ANOVAs were calculated on the Bayley Verbal score and Bayley Performance score. As would be expected, there were significant age effects on both measures. The mean scores for the 21 verbal items from the Bayley administered at 18, 24, and 30 months of age were 5.2, 11.4, and 17.2, respectively. For the 22 performance items administered at 24 and 30 months of age, the mean scores were 10.8 and 15.1. There were no significant sex differences or significant interactions of age × sex, and all subsequent analyses were carried out with the data from male and female subjects combined.

*Consistency in Rearing Conditions*

Since individual children were exposed to different rearing conditions, the question arises as to whether there was consistency in their experiences from one time period to another. To address this issue, the observational data for each child were grouped into five different age periods, and correlations were then computed between the variables from one period to the next. There was significant consistency in the extent to which the children were talked to and held and in the frequency of responses to their vocalizations (see Table 3).

The durations of social interactions was stable over the first 6 months of observations but varied subsequently. Responsiveness to crying remained stable only through the third observation period; there were no significant correlations from one period to the next after 25.5 months. The extent to which the children were cared for physically and were touched showed great variability from one period to the next, and there were no significant correlations in these measures between periods. To summarize, the individual differences that children experienced in the extent to which they were held and talked to remained relatively constant over the 15-month observation period.

## Consistency in Toddler Development

*Test performance.*—Correlations were calculated between scores on the measures administered at 18, 24, and 30 months. The Bayley Mental Scale showed consistency in individual differences. The correlations between total scores at succeeding periods were both $r(94) = .55$, $p < .01$. The correlation between the total score on the verbal items administered at 18 months and the total score on all items administered at 30 months was $r(100) = .42$, $p < .01$.

*Toddler behavior in the home.*—Correlations were computed between the total duration of toddler behaviors from one of the five age periods to the next and from the first

TABLE 3

CORRELATIONS BETWEEN AGE PERIODS

| | Age Period 1–2 | Age Period 2–3 | Age Period 3–4 | Age Period 4–5 | Age Period 1–5 |
|---|---|---|---|---|---|
| Home variables: | | | | | |
| Physical care | ... | ... | ... | ... | ... |
| Touches | ... | ... | ... | ... | ... |
| Holds/carries | .49 | .22 | ... | ... | .31 |
| Social interaction | .31 | .38 | ... | ... | ... |
| Talks to | ... | ... | .33 | .32 | ... |
| Responsiveness to vocalization | .25 | .26 | .26 | ... | .27 |
| Responsiveness to distress | ... | .21 | .22 | ... | ... |
| Child behaviors: | | | | | |
| Child plays | ... | ... | ... | ... | ... |
| Child talks | ... | .28 | .42 | .39 | .38 |
| Child smiles | ... | .26 | ... | .24 | ... |
| Child cries | ... | ... | ... | ... | ... |

NOTE.—All correlations shown, $p < .05$.

to the last. There was no consistency in the total amount of play with objects, but there was strong consistency in the amount of toddler vocalizations. Individual differences were stable across the entire age range (see Table 3). In the affective domain, there was some limited stability in the amount that toddlers smiled but no consistency in the amount of distress.

*Relations between Rearing Factors and Development*

*Bayley Mental Scale scores: 24 and 30 months.*—Correlations were calculated between the mean percentages over all home observations carried out when children were between 15 and 24 months of the seven rearing variables (physical care, holds or carries, touches, talks to, social interaction, responsiveness to vocalizations, and responsiveness to crying) with total score on the Bayley items at 24 months. To control for variation in the ages of the children at the time of the home observations, the mean age was partialed out of these correlations. Bayley total score correlated significantly with talks (see Table 4) and at a nearly significant level with responsiveness to toddler vocalizations, $p < .06$. The latter was significantly associated with total number of verbal items passed, $r(97) = .28$, $p < .01$.

Correlations were calculated between the mean percentages over all home observations carried out when the children were between 15 and 30 months of the seven rearing variations with the total score on the Bayley items at 30 months. The mean age of observation was again partialed out of the correlations. Bayley total score correlated significantly and positively with three rearing variables: talks, social interaction, and responsiveness to toddler vocalizations (see Table 4), and negatively with hold/carries.

*Bayley Motor Scale scores.*—The only home variable associated with the overall score on the motor items was the number of intervals that the child was held, and this association was negative, as was the correlation for the Bayley Mental score.

*Toddler affect.*—To assess the child's predominant emotional state, the total percentage of time in the last two observations that the child cried or smiled was calculated, and correlations were computed between these percentages and the rearing variables considered over the 15-month period (see Table 4). Children who smiled a great deal at 30 months were responded to more and involved in far more social interaction than children who smiled less. Children who cried at this age had been involved in fewer sustained social involvements.

*The Effects of Rearing Conditions Independent of Toddler Characteristics*

It appears from the evidence reported so far that the social rearing conditions experienced by these Embu toddlers of Kenya influenced their cognitive and emotional development. However, it can be argued that the child elicits physical and social care from the parent, so that associations between rearing conditions and child development really reflect continuities in the child. To address this issue, two multiple regression analyses were carried out in which a measure of the children's earlier verbal abilities was entered prior to the rearing variables as predictors of the total score on the Bayley scale at 30 months.

TABLE 4

CORRELATIONS BETWEEN HOME VARIABLES AND CHILD CHARACTERISTICS

| Home Variables | 24-Month Bayley Mental Score | 30-Month Bayley Mental Score | 30-Month Bayley Motor Score | Frequency of: Cries | Frequency of: Smiles |
|---|---|---|---|---|---|
| Physical care | ... | ... | ... | ... | ... |
| Holds/carries | ... | −.24 | −.24 | ... | ... |
| Touches | ... | ... | ... | ... | ... |
| Talks | .26 | .19 | ... | | |
| Social interaction | ... | .29 | ... | −.19 | .34 |
| Responsiveness to vocalization | ... | .23 | ... | ... | .24 |
| Responsiveness to distress | ... | ... | ... | ... | ... |

NOTE.—$p < .05$ for all correlations shown. For 24-month Bayley Mental score, $n = 99$; for 30-month Bayley Mental score, $n = 105$; for 30-month Bayley Motor score, $n = 103$; for Frequency of cries/smiles, $n = 106$. Mean age of home observation has been partialed out of all correlations.

In the first regression, total score on the Bayley Scale administered at 18 months was entered first, and the four home interaction measures identified as related to outcome were entered next with no order specified. The verbal score accounted for 18% of the variance, and the home interaction measures accounted for an additional, significant 14% of the variance in 30-month Bayley score, $F(4,98) = 4.78$, $p < .001$. In the second multiple regression, mean number of intervals in which the toddler vocalized during home observations between 15 and 21 months of age was entered into the multiple regression prior to the four home interaction variables. The frequency of toddler verbalization accounted for 4% of the variance in Bayley score at 30 months, while the interaction measures accounted for a significant additional 22% of the variance, $F(4,95) = 7.02$, $p < .001$. Thus, the extent of verbal and social interaction seemed to influence cognitive development regardless of the verbal skill or loquaciousness shown by the 18-month-old.

*Parental Literacy and Child Abilities*

As reading and writing literacy were highly intercorrelated ($r$'s = .82 and .84), only the scores for maternal and paternal reading skills were analyzed in this article. Although the reading abilities of the two parents were correlated, $r(110) = .35$, $p < .001$, only fathers' reading scores, and not mothers' reading scores, correlated significantly with both the Bayley Mental and Motor scores at 30 months, $r$'s$(105) = .24$, $p < .007$.

To determine whether the home environment was associated with development as a function of paternal educational level, a hierarchical regression was run, with fathers' reading score entered prior to the four home interaction variables to predict Bayley Mental Scale scores. Paternal literacy accounted for 6% of the variance in 30-month Bayley score, and home rearing conditions accounted for an additional, significant 16% of the variance, $F(4,101) = 5.21$, $p < .001$. Thus, specific rearing conditions were associated with the toddler's cognitive development regardless of the educational level of the father. While paternal literacy and home interactions were significantly related to development, the associations were only moderate in strength (adjusted $R^2 = .18$).

## Discussion

There has been increasing recognition of the need for observations of child-rearing conditions in order to make sense of the differences in the ways that children from varying cultural groups develop (Whiting, 1981). Cross-cultural studies are important not only for identifying variations in child development as a function of different rearing patterns, but also for identifying similarities in relations between rearing factors and child development across cultural settings.

The home environment was associated with the child's development in much the same way in this part of rural Kenya as has been described in the United States. For this age group of children, the most consistently important variables reflected the verbal and social milieu in which the child was raised. The amount of time the child was talked to and responsiveness to the child's vocalizations predicted subsequent developmental status. These associations might have been less evident in a cultural group that was less verbal and interactive. Both the adults and the toddlers talked to each other frequently in the home setting. The meaning of verbal interactions and the aims of child rearing in this cultural group have yet to be explored.

Physical care and responsiveness to distress were not associated with developmental scores for these 15–30-month-olds. However, the amount of time the child was held or carried correlated negatively with development. This finding replicates an observation made with 10 7–16-month-old Logoli children by Munroe and Munroe (1984) and with 12-month-old Zambian children by Goldberg (1977), who suggested two hypotheses to explain the negative association. First, carrying a child after the first year of life may restrict exploration of the environment, so that the child's development is deleteriously affected by this practice. Alternatively, children may be carried in the second year of life who are already developing more slowly. Data on physical maturity, illness, and food intake that will become available on this sample should allow us to determine whether children who were carried more were seriously ill or malnourished.

The influence of siblings and peers appeared to be quite important for the Embu toddlers' development. Older sisters were frequently the caregivers who listened to and talked to their younger sibling. Furthermore, those toddlers most involved in sustained social interaction developed the most rapidly, and social interactions almost always involved other children rather than adults. The importance of polymatric rearing for the development of infants in another tribe in Africa has been pointed out (Leiderman & Leiderman, 1974). There appears to be less shared

rearing with other adults among the Embu than among other tribes in Kenya, possibly because most families are monogamous and nuclear. Perhaps older female siblings fill a role played by adults in other tribes.

Although the home-rearing variables accounted for only a small part of the variance in toddler development, as is true in Western studies, the association between verbal stimulation and developmental status held regardless of the child's initial level of development. This was particularly striking since verbal skill and verbosity at 18 months may have already been influenced by earlier social and verbal interactions in the home. Thus, appropriate verbal stimulation may be helpful in the second to third year of life even for slowly developing toddlers. On the other hand, there may be characteristics of the toddler other than their verbal abilities that elicit verbal and social responses. Furthermore, the predictive validity of the Bayley Mental Scale at 30 months is unknown for this culture, although the Bayley Scale administered at age 2 years is predictive of later intelligence in the United States (Honzik, 1976; McCall, 1979). We are currently conducting a follow-up study of this group at 5 years of age that should allow us to assess the predictive validity of the measures employed in this study.

The independence of the effects of rearing variables on development from the effects of other home conditions is difficult to determine. We addressed this issue by examining the unique part of the variance in development accounted for by rearing and the unique part accounted for by parental literacy. The ability of fathers to read is tied to the economic conditions of the household as well as to the intelligence and education of the parents. The fact that both paternal literacy and rearing conditions influence the children's development suggests that development may be advanced among toddlers in this culture who are talked to, responded to, and involved in social interactions, whatever the economic and educational level of their families.

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