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Morinda revisited: Changes in nutritional well-being and gender differences after 30 years of rapid economic growth in rural Punjab, India

F. James Levinson, Sucheta Mehra, Dorothy Levinson, Anita Kumari Chauhan, Guy Koppe, Brian Bence, and Astier M. Almedom

Abstract

A follow-up study of malnutrition and its determinants among children 6 to 24 months of age was carried out in rural areas of Punjab State in India 30 years after the original study, and following a period of rapid economic growth. The original 1971 study had found a high prevalence of mortality and malnutrition and the worst gender difference in nutritional status ever recorded in an Indian study. The 2001 follow-up study found dramatic reductions in child mortality, child malnutrition, gender-based imbalances in child well-being and care, and family size, the result of participatory economic growth coupled with broad-based educational, health, and family-planning services. Despite overall improvements in caloric intake, however, 40% of lower-class children in 2001 were still consuming less than 50% of their caloric allowance. With minimal gender-based abortion and significantly reduced neglect and mortality of female children, gender balance among children in this area of rural Punjab improved markedly over the 30-year period.

Key words: Childhood malnutrition, gender, India, Punjab

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Introduction

In 1971, the first author, in collaboration with the Government of India Food and Nutrition Board, carried out a study of the determinants of malnutrition among children aged 6 to 24 months in 18 villages surrounding the market town of Morinda in Rupnagar (formerly Ropar) District in Punjab State in India [1]. That study, which identified important behavioral and economic determinants, also found substantial malnutrition (47.8% moderate and severe malnutrition according to the Harvard standards and the Gomez classification utilized at that time) and the most extreme gender disparity in nutritional status ever recorded in an Indian study (87.5% of severely malnourished children, according to these same standards, were girls).

In the 1971 study, both nutritional intake and infection proved to be highly important determinants of nutritional status. When food intake was used as the independent variable, the most important determinants, beyond gender and age, were economic status, particularly among the lower income, landless Ramdasias, and caring practices relating to age of introduction of complementary food, particularly for the landed, higher income Jats. Diarrheal infection proved to be the most important component of infection.

Since 1971, the Punjab has experienced remarkable agricultural development (see table 1) plus major increases in rural electricity and road construction [2]. The magnitude of these changes is reflected dramati-

TABLE 1. Indicators of agricultural development in Punjab State in 1971 and 2000

Indicator	1971	2000
Wheat yield (kg/ha)	2,270	4,696
Maize yield (kg/ha)	1,470	2,577
Percentage of cultivated land that is irrigated	74%	96%

ha, hectare.

cally by the number of registered tractors in Rupnagar District: 164 in 1971 and 17,013 in 2000 [2]. Incomes in the study area relative to the cost of living more than doubled over this 30-year period, both among the traditionally landowning Jat caste (all Sikhs) and the traditionally landless Ramdasias (Sikhs and Hindus). (It should be noted that this period of rapid economic growth in the Punjab also included a period of political instability resulting from a Sikh separatist struggle.) Several of the tables presented in this article distinguish findings for the Jats and Ramdasias as well as a third heterogeneous caste group of "others." During the same period, the Punjab State Government introduced an intensive immunization campaign, launched a massive safe water and sanitation program in rural areas, intensified family-planning services, and introduced compulsory primary education while continuing its adult literacy campaigns.

The 2001 study, undertaken 30 years later, was designed to assess the changes in nutritional status, mortality, gender discrimination, and malnutrition causality that took place over this period of rapid economic growth. This paper presents findings on the first three of these sets of changes. Comparative analysis is somewhat limited, in that although tables from the 1971 study are available, the raw data are not. In a postscript, the paper examines the effect in this area of gender-based abortion, which has had a substantial effect on gender balance in Punjab State as a whole.

Methods

Sample

A cross-sectional household survey was conducted in December 2001 in the same 18 villages studied in 1971, plus 3 villages in the same area that had been bypassed in the earlier study. Unlike the initial study (sample size, 496), which sought to collect data on every 6- to 24-month-old child in every village, the 2001 study, for purposes of convenience, utilized *Anganwadi* workers of the Integrated Child Development Service (ICDS) project (nonexistent in 1971) to identify a sample of 202 children. ICDS, developed by the Government of India in 1979, now provides services for preschool-age children and pregnant women in nearly 90 percent of India's development blocks. The *Anganwadi* worker (AWW), responsible for delivery of these services at the village level, takes her title from the *anganwadi* or traditional courtyard in which she normally works.

The result was a sample somewhat biased toward lower-income and non-Jat households (who are more likely to utilize ICDS services, while their more affluent neighbors frequently seek private health services). Neither the investigators nor the *Anganwadi* workers were aware of any children who were not served either by the combination of ICDS and primary health care services or by private health practitioners. The 2001 sample also was slightly younger (see table 2).

Survey instrument

The survey instrument, which was similar to that used in the original survey, was pretested, modified, and administered by three of the study authors, assisted by staff of the Punjab Department of Health located in Morinda. The 2001 questionnaire updated the family possessions or wealth index and collected more detailed pregnancy histories to permit an examination of the gender-based abortion issue. Anthropometric data were collected to estimate nutritional status. Data were collected on food intake and morbidity, particularly diarrheal infection, the immediate determinants of nutritional status, and on economic status (income calculations plus the wealth index), family size, and caring practices as underlying determinants. Information also was collected on the water and sanitation practices of the household and the pregnancy history of the mother.

Anthropometric procedures

Weights and heights of the children were measured at the time that other data on the child and the household were collected. Weight was measured with minimal clothing and without shoes to the nearest 100 g. Length was measured with a locally constructed length board, following the standardized procedure. The correct age of the child was determined both by asking the mother and by asking the *Anganwadi* worker to check her register.

Weight-for-age data from the 2001 follow-up study were analyzed in three ways: by using the Harvard standards and the Gomez classification to permit a comparison of 2001 data with the 1971 data; by using the percentage of median of the Centers for Disease Control/World Health Organization (CDC/WHO)

TABLE 2. Samples of the 1971 and 2001 studies in Morinda disaggregated according to caste and age of child

Characteristic	1971 %	1971 No. (n = 496)	2001 %	2001 No. (n = 202)
Caste				
Jat	42.1	209	24.8	50
Ramdasia	39.1	194	43.1	87
Other	18.8	93	32.2	65
Age (mo)				
6 – <12	32.9	163	33.7	68
12 – <18	31.6	157	39.6	80
18 – 24	35.5	176	26.7	54

international growth standards, again using the Gomez classification; and by conversion of the latter values to Z scores using the Nutritional Anthropometry (Epi Info 2002 System) from the Division of Nutrition, CDC, to permit international comparisons. According to the Gomez classification, normal: ≥ 90% of Harvard weight-for-age standards; mild malnutrition: 89% to 75%; moderate: 74% to 60%; severe: < 60% [3]. Using Z scores, normal: Z score ≥ –1; mild malnutrition: Z score ≥ –2 and < –1; moderate: Z score ≥ –3 and < –2; severe: Z score < –3. It should be noted that the Harvard standards pool the genders, whereas CDC/WHO provides gender-specific standards.

Caloric intake

The caloric intake of each child was determined by a standard 24-hour food-recall questionnaire using the same standardized vessels and utensils that had been used in 1971. The weight of each food was obtained for these vessels and utensils, translated into available calories using the standard Indian reference [4], and finally compared with nutrient allowances set by the Indian Council of Medical Research. Information also was collected on the breastfeeding status of the child (caloric intake data are presented as a percentage of these allowances rather than as absolute caloric figures, which are no longer available from the 1971 study).

Infection

Data were collected on morbidity histories of the children. In addition, the index developed in the 1971 study to capture the frequency and severity of diarrheal infection was used as well in 2001.

Economic status

The wealth indices developed for the two studies, although useful for causality analysis on their respective samples, were not appropriate for comparative analysis (the 2001 wealth index included such items as televisions and VCRs, which were not generally available in 1971). Household income data, however, were carefully collected in both studies, and the concept of monthly income was well understood by all households. The imputed value of home-grown and consumed food was included.

Caring practices and beliefs

An index of deleterious child-feeding and pregnancy self-care practices was developed for subsequent causality analysis of the 2001 sample. Data comparable across the two surveys were the age of introduction of complementary food; continuity of feeding during bouts of infection; and beliefs about the causes of severe malnutrition.

Self-care data relating to the mother's most recent pregnancy collected in the 2001 survey include the regularity of daytime rest during pregnancy and the amount of food consumed during pregnancy relative to prepregnancy

Birthweight data are not yet regularly collected for rural home births.

Results

Nutritional status

Table 3 presents weight-for-age results from the 2001 survey, using the Harvard standards according to the Gomez classification (percentage of median), the CDC/WHO standards according to the Gomez classification, and Z scores according to the CDC/WHO standards. With this data set, the three classifications provide similar estimates for severe malnutrition, but vary considerably in their estimates of mild and moderate malnutrition. The prevalence figures for malnutrition (moderate plus severe) according to the Harvard standards, which are utilized here for comparison purposes

TABLE 3. Nutritional status from the 2001 survey using weight-for-age data and three classification systems

		% (no.) of children according to classification system		
Gender	Nutritional status	Harvard	CDC/WHO % of median	CDC/WHO Z scores
Male	Normal	41.0 (48)	35.9 (42)	40.2 (47)
	Mild malnutrition	51.3 (60)	40.2 (47)	49.6 (58)
	Moderate malnutrition	7.7 (9)	23.1 (27)	10.3 (12)
	Severe malnutrition	0 (0)	0.9 (1)	0 (0)
Female	Normal	21.2 (18)	43.5 (37)	35.3 (30)
	Mild malnutrition	54.1 (46)	28.2 (24)	48.2 (41)
	Moderate malnutrition	23.5 (20)	27.1 (23)	16.5 (14)
	Severe malnutrition	1.2 (1)	1.2 (1)	0 (0)

across the two surveys, are somewhat lower than the Z scores for males but much higher than those for females, in part because the Harvard standards pool the genders.

By using the Harvard standards and the Gomez classification, the nutritional status of children from the two surveys can be compared. These results are presented in table 4. The prevalence of malnutrition (moderate plus severe) decreased dramatically, from 47.8% in 1971 to 14.9% 30 years later. The prevalence of severe malnutrition fell from 8.3% to 0.5%, and the percentage of "normal" children more than doubled over the 30-year period. Remarkably, among the Jat children, the prevalence of malnutrition fell from 38.8% to 2.0%, whereas among the poorer Ramdasia children, malnutrition was reduced by a still impressive 66%.

Table 5 compares malnutrition prevalence by gender. The prevalence of moderate plus severe malnutrition among girls decreased by 75%, from 68.6% in 1971 to 17.5% in 2001 (compared with a 68% reduction among boys). Although a gender gap still exists, its significance with such small numbers is greatly reduced.

Mortality and family size

These changes in nutritional status are consistent with the reduced child mortality reflected in table 6. As indicated on the right side of table 6, the average number of liveborn siblings of the children studied decreased eightfold, from 0.64 (meaning, on average, more than one dead sibling for every two children studied) in 1971 to 0.08 in 2001.

The left side of table 6 highlights an important causal factor in this improved well-being, the reduction in family size. In 1971, the average child studied had 2.22 living siblings. Thirty years later, the figure was less than 1 (0.93).

Caloric intake

For this young child population as a whole, caloric intake increased by 49% from an average of 61.3% of caloric allowances to 91.5% (see table 7). Here, and in table 8, the caste/class disaggregation is particularly important. For the Jats, although the mean caloric intake in 2001 is, on average, 115% of allowances, and although the percentage of Jat children consuming 100% of caloric allowances or higher has increased nearly fivefold over the 30 years, only just over half of Jat children (52%) are meeting their total caloric needs, while fully 20% are consuming less than half of the caloric allowance. Breastfeeding, as in 1971, was nearly universal into the second year.

Among Ramdasia children, although the proportion of children consuming at least 100% of allowances also has increased dramatically (sixfold), only 31% of Ramdasia children are actually consuming this much, while an alarming 40.2% are consuming less than 50% of their caloric allowances (not significantly better than 30 years earlier). A disaggregation of these data indicates that, in 2001, poorly fed Ramdasia children are evenly distributed by gender.

TABLE 4. Comparison of nutritional status in 1971 and 2001 according to the Harvard standards and the Gomez classification (weight-for-age)

Group	Normal (%)		Mild malnutrition (%)		Moderate malnutrition (%)		Severe malnutrition (%)	
	1971	2001	1971	2001	1971	2001	1971	2001
Jats	19.6	48.0	41.6	50.0	35.2	2.0	3.6	0.0
Ramdasias	6.9	26.4	35.8	54.0	45.1	18.4	12.3	1.1
Other	20.8	29.2	31.3	52.3	37.5	18.5	10.4	0.0
Total	14.8	32.7	37.3	52.5	39.5	14.4	8.3	0.5

TABLE 5. Prevalence of malnutrition according to gender in 1971 and 2001

Degree of malnutrition	1971 (%)		2001 (%)	
	Male	Female	Male	Female
Moderate	32.1	54.2	11.0	17.4
Severe	2.8	14.4	0	0.1

TABLE 6. Living and dead siblings per sample child according to caste in 1971 and 2001

Caste	No. of living siblings		No. of live-born dead siblings	
	1971 (mean)	2001 (mean ± SD)	1971 (mean)	2001 (mean ± SD)
Jats	2.16	0.90 ± 0.84	0.49	0.04 ± 0.20
Ramdasias	2.36	0.93 ± 0.96	0.85	0.06 ± 0.23
Other	2.08	0.94 ± 0.95	0.53	0.17 ± 0.52
Total	2.22	0.93 ± 0.92	0.64	0.08 ± 0.35

Other factors associated with reduced malnutrition

Other study results are summarized in table 9. Literacy of mothers increased nearly fourfold over the 30-year period (from 22.6% to 84.8%), while the earlier belief that severe malnutrition is caused by the casting of a shadow of an evil person or spirit, prevalent among 55.8% of mothers in 1971, was nonexistent 30 years later. The average age of introduction of complementary food dropped from 10.6 months to 7.2 months.

Although information was not collected on the process of change mediation, it appears that changes in practices resulted from some combination of literacy and media exposure emanating from the broader educational opportunities that had become available and the health education provided in clinics. Relatively little seems to have been the result of explicit nutritional counseling within the ICDS program.

With the use of the same index of diarrheal frequency and severity in both studies, the average 2001 score was less than half that in 1971. Immunizations and safe water supply, sporadic in 1971, were universal among this population in 2001. Real income (in constant rupees) increased over the 30-year period by 2.2 times among Jats and 2.16 times among Ramdasias.

Data analysis

The statistical software used for the study was SPSS Version 11.0 for Windows. Because the raw data from 1971 are no longer available, there were limitations to the comparative analysis that could be done. Importantly, the calculation of ranges, standard deviations, and statistical significance was not possible.

TABLE 7. Percentage of daily caloric allowances consumed according to caste in 1971 and 2001

Caste	1971 (mean)	2001 (mean ± SD)
Jats	63.6	115.8 ± 82.6
Ramdasias	59.2	78.1 ± 63.6
Other	60.7	92.0 ± 79.4
Total	61.3	91.5 ± 75.0

Discussion

Improvements in nutritional status among these young children over the 30-year period have been dramatic. Even in Punjab, among India's most developed states, malnutrition prevalence in 1971 was high on a spectrum of developing countries. In 2001, by contrast, the figures for this population are comparable to those found in such semiindustrialized countries as Mexico and Turkey, while among the Jats, nutritional status is comparable to that found in Russia.

Explanations for this remarkable improvement are not difficult to find. The development process in the rural Punjab, combining rapid and participatory economic growth with the broad-based provision of educational, health, and family-planning services, underlies both this change in nutritional status and the eightfold decrease in child deaths over the period. Importantly, the fourfold increases in the literacy of young mothers and universal access to safe water and immunizations have protected the large majority of this population of children against serious nutrition and health problems.

Equally striking is the improvement in the nutri-

TABLE 9. Findings on other factors associated with malnutrition in 1971 and 2001

Factor	1971	2001
Literacy of mothers (%)	22.6	84.8
Superstitious belief that casting a shadow causes severe malnutrition (%)	55.8	0
Mean age of introduction of complementary food (mo)	10.6	7.2
Index of frequency and severity of diarrheal infection (range, 0–7)	1.99	0.94
Immunizations up to date (%)	Sporadic	100%
Safe water supply (%)	Sporadic	100%
Income (constant rupees)		
Jats	2.20 times higher in 2001	
Ramdasias	2.16 times higher in 2001	

TABLE 8. Percentage of children consuming specific percentages of daily caloric allowance according to caste in 1971 and 2001

	% of daily allowance consumed							
	≥ 100%		75%–99%		50%–74%		< 50%	
Caste	1971	2001	1971	2001	1971	2001	1971	2001
Jats	10.9	52.0	16.1	12.0	45.5	16.0	27.5	20.0
Ramdasias	5.2	31.0	14.4	12.6	43.8	16.1	36.6	40.2
Other	4.5	35.4	18.0	20.0	42.7	12.3	34.8	32.3
Total	7.5	37.6	15.8	14.9	44.3	14.9	32.4	32.7

tional status of young girls. From an imbalance in nutritional status in 1971 as serious as that found anywhere in the world, malnutrition among young girls fell to a quarter of earlier levels, and the male-female differentials were reduced.

Here explanations surely lie in the economic and educational improvements that have taken place over the 30-year period, coupled with a highly significant reduction in the mean number of children in these young families (from 3.2 to 1.9). With a much higher proportion of young children surviving, and an aggressive family-planning program, young couples clearly have found it to their advantage to have smaller families. With smaller families, a much smaller number of less desired female children, and incomes adequate to support female as well as male children, young girls are now fed better and kept healthier.

These understandings were further reinforced by questions asked of both mothers and grandmothers in the 2001 study about gender preferences. In that study, 72.5% of mothers indicated a desire (at the time of marriage) for two children (one boy and one girl); 93.6% of mothers and 93.8% of grandmothers indicated a desire to educate male and female children in the household equally; and 97.1% of mothers and 94.8% of grandmothers indicated a willingness for female children to seek outside employment after schooling.

Although nutritional status, health status, and child survival improved significantly, food consumption among young children remains an issue of some concern. Relative to the 1971 findings, the proportion of children consuming adequate calories improved markedly, both among the more advantaged Jats and among the less advantaged Ramdasias. However, at the lower end of the food-consumption spectrum, over 40% of Ramdasia children and 20% of Jat children were still consuming less than 50% of their caloric allowance in 2001. Whereas in 1971 most of the poorly fed children were girls, this was not the case in 2001. There also may be a problem at the upper end of the food-consumption spectrum. Among Jat children, whose caloric intake averaged 115% of allowances, a significant proportion are consuming far more than 100 percent of allowances, raising concerns about childhood obesity. (The investigators, however, noticed few cases of overt obesity.)

With good health care and safe water, most of those children who were inadequately fed, particularly among the Jats, managed to grow reasonably well and to survive minor childhood illness. (The specific mechanisms by which this occurs would be worthy of future study.) However, such low levels of caloric intake clearly leave these children vulnerable, particularly to a more serious epidemic of childhood illness. The problem deserves attention. At present, ICDS services cover most of Punjab State, but with services that still pay inadequate attention to the nutritional well-being of children under the age of two. ICDS services, well targeted to children at the low end of the nutritional spectrum and with a strong behavioral-change communications component, could be expected to remedy this gap.

A postscript on gender-based abortion and gender balance

Serious concerns have been raised, particularly in northern and western India and in China, about the problem of gender-based abortion. The traditionally strong preference for sons in these areas, relating to issues ranging from social security and inheritance to death rituals and dowries, has led, in the past, to the neglect of unwanted or "excess" girls (note the unusually high percentage of malnourished females in 1971) and, in extreme cases, to infanticide. With the advent of ultrasound testing, gender-based abortion has provided a newer means of eliminating such "excess" females.

The effects of this technology are reflected in recent Punjab State census data indicating that among children 6 years of age or younger, the number of girls per 1,000 boys decreased from 875 in 1991 to 793 in 2001.

Data carefully gathered as part of this study in 2001 indicate that sonogram testing and gender-based abortion are relatively rare in this rural area. In the 204 sample households, nine women had had sonograms, four of these for medical problems. Of the remaining five women (three Jat, two Ramdasia; three with two or more previous female children, two with one previous female child), four tests found a male fetus, while one test found a female fetus, which resulted in an abortion.

The likelihood of increases in future sonogram testing appears low in Punjab, given newly enforced state laws (including large fines and the registration and monitoring of private clinics) and increased vigilance by religious communities.

With minimal gender-based abortion and significantly reduced neglect and mortality of female children, gender balance in this area of rural Punjab actually has improved, from 894 girls per 1,000 boys 6 years of age or younger in 1971 to 965 in 2001.

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Behavior-change trials to assess the feasibility of improving complementary feeding practices and micronutrient intake of infants in rural Bangladesh

Joel E. Kimmons, Kathryn G. Dewey, Emdadul Haque, J. Chakraborty, Saskia J. M. Osendarp, and Kenneth H. Brown

Abstract

This study used simple rapid-assessment techniques to test the feasibility of increasing the consumption of complementary foods by infants by asking mothers to increase meal quantity or frequency or by altering the viscosity/energy density of the food. The feasibility of using micronutrient supplements either added directly to food or administered as liquid drops was also examined. The study was conducted in rural Bangladesh and involved four separate short-term behavioral change trials. Depending on the trial, fieldworkers recruited 30 to 45 infants 6 to 12 months of age. Following recommendations to increase the amount of food provided to infants, the mean intakes from single meals increased from 40 ± 23 g on day 1 to 64 ± 30 g on day 7 (p < 0.05). In a second trial, the mean meal frequency increased from 2.2 ± 1.3 on day 1 to 4.1 ± 1.3 on day 7 (p < 0.05). Provision of high-energy-density diets, prepared by decreasing viscosity with α-amylase or by hand-mashing rice and dhal into a paste before feeding, increased single-meal energy consumption from 54 ± 35 kcal to 79 ± 52 kcal or 75 ± 37 kcal (p < 0.05), respectively. Both types of micronutrient supplements were well accepted and used according to recommendations. In conclusion, it was possible to change short-term child-feeding behaviors to promote increased food intake, meal frequency, energy density, and micronutrient consumption. Because each of these interventions lasted for only about 1 week, however, the long-term sustainability of these changes is not known. Moreover, the effect of increased feeding of complementary foods on intakes of breastmilk and total daily consumption of energy and nutrients requires further study.

Key words: Bangladesh, breastfeeding, complementary feeding, energy density, infant nutrition, meal frequency, micronutrient, viscosity

Introduction

Critical components of appropriate complementary feeding include the introduction of foods other than breastmilk at about six months of age, adequate energy density and frequency of feeding of these complementary foods, and satisfactory nutrient density of these foods [1]. Implementation of these guidelines at the local level requires an understanding of current child-feeding practices, the factors that influence these practices, and possible constraints to improving them. The Bangladesh Integrated Nutrition Project (BINP) finished in 2001 and has now been succeeded by the National Nutrition Program (NNP). The BINP targeted children less than two years of age, but prior to this study it had not yet developed educational messages to improve complementary feeding practices. Therefore, we conducted a series of studies using quantitative and qualitative techniques to determine the optimal means of improving complementary feeding of rural Bangladeshi infants, considering issues of local feasibility, acceptability, and likely sustainability. Prior to the studies reported herein, we conducted a weighed dietary intake study of 135 infants between 6 and 12 months of age. The average daily energy intake from complementary foods was only 134 kcal (561 kJ), whereas the expected intake, given the actual breast milk intakes by infants in the study, was 193 kcal (808 kJ) at 6 to 8 months and 241 kcal (1,008 kJ) at 9 to 11 months [2].

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Meal frequency and energy density of complementary foods were generally consistent with recommendations, but the amounts offered were less than recommended. Despite this, the average consumption was only 73% of the amount of food offered. The foods offered and diets consumed during the weighed-intake study were well below recommended levels with respect to several micronutrients. Accordingly, the behavior-change trials reported herein were designed to explore the flexibility of local infant-feeding practices with regard to increasing the amount of food offered at each meal, increasing meal frequency, using recipes with different viscosities and energy densities, and enhancing micronutrient intake either by adding micronutrient supplements to existing foods at the time of preparation or serving, or by providing liquid supplements directly to infants.

Methods

General

All studies were conducted in several small villages in Matlab thana, Comilla District, Bangladesh. The Matlab field research unit of the International Centre for Diarrhoeal Diseases Research, Bangladesh (ICDDR, B) Centre for Health and Population Research served as the project's central office. Matlab is located 55 km southeast of Dhaka in the low-lying deltaic plain that makes up most of southern Bangladesh. The human subjects committees at the University of California, Davis, California, USA and ICDDR,B approved the research protocol.

The villages were within an hour's travel from the ICDDR,B Matlab Centre by a nonmotorized boat. Within these villages, all infants who were 6 to 12 months of age and receiving complementary foods along with breastmilk were eligible to participate in the studies. All infants in each village were recruited, and new villages were added to the study as needed to attain the desired sample size. For the most part, different subjects were enrolled in each of the four studies, although a few of the subjects participated in more than one. Oral consent was obtained from mothers who agreed to participate. Study subjects were visited on alternate days for the duration of each study.

To gain insight into the feasibility and acceptability of the behavior changes, mothers were asked specific questions and also encouraged to comment freely on their experience. Data were collected by fieldworkers who were selected from the villages in which the studies took place. All questions were asked in the local Bangla dialect. Three native Bangla speakers who were fluent in English participated in discussions with the fieldworkers to ensure that the questions were asked as intended and in a consistent manner. A single person translated the responses into English only after the meaning of all responses was agreed upon by the study team.

During each study, mothers were advised not to change their breastfeeding practices, and were told that any modifications of the infants' foods or feeding practices were intended to complement breastmilk, not replace it. The fieldworkers also emphasized the importance of hygiene, suggesting that foods be freshly prepared; hands, dishware, and eating utensils be washed before meals; foods be stored in clean, sealed containers; and leftover foods be reheated appropriately before feeding.

Meal quantity study

This study was undertaken to determine the feasibility of using an educational message to increase the quantity of food offered to and consumed by infants at each meal. On the first day of the study, before any feeding recommendations were given, the amount of food offered to and consumed by each of 30 infants at a single meal was measured, as well as the time the mother spent feeding. After the feeding session ended, the mother was asked to try to continue the feeding to see if the child would eat more. The observer recorded whether the infant still appeared to be hungry, based on whether the infant consumed the food eagerly and with ease. The intake from this second offering was also weighed. The age-specific amount of energy to be given daily was then demonstrated by showing the mother the quantity of rice and dhal necessary to satisfy her infant's theoretical energy needs. After the initial recommendations and demonstrations, the participants were asked to increase the amount of food they fed to their infants at each meal. Observations of a single meal were then repeated on alternate days for seven days. No food was supplied to the study participants.

On each subsequent day of observation, we observed the child being fed at the usual mealtime. The amount consumed and time spent feeding were measured at this single meal. Fieldworkers observed the meals and recorded why the mother stopped feeding (coded as "infant finished all of the food," "infant appeared satiated," "mother had other responsibilities," or "other reason"); whether the infant was offered more food after he or she appeared to be satiated; the viscosity of the food; and the infant's acceptance of the food.

Operational definitions for the above outcomes were developed during training sessions with input from the fieldworkers. An infant was judged to be satiated after a complementary feeding if he or she began losing interest in being fed and began playing or moving about; appeared satisfied by becoming silent or calm or by falling asleep; or refused to take more food or spit food out. The fieldworkers judged viscosity by observation and recorded it using a five-point scale in which values were defined as watery (like tea), thicker (like lentil soup dhal), thicker (like halua pudding), wet solid (like rice), or dry solid (like biscuit). Acceptance of the food was ranked on a four-point scale, ranging from 1 (the infant ate the food readily) to 4 (the infant spit the food out).

In addition, the fieldworkers asked the mothers open-ended questions about why they fed the quantity they did, their impressions or comments about being asked to increase meal size, and how many times they fed their infant on the previous day.

Meal frequency study

This study was undertaken to determine the feasibility of using an educational message to increase the frequency of complementary food meals. Thirty mothers were asked to feed at least three meals per day, and more if possible. They were advised that snack foods (amounts less than 10 g) were not to be considered as meals, and they were encouraged to continue to give snacks as usual. A meal was defined as a separate feeding of greater than 10 g. The fieldworkers showed the study mothers a 10-g portion of rice to assist them in making this distinction. Meal frequency was determined on each subsequent alternate-day visit by recall of the previous day.

On the first and last day of the study, the mothers were asked, “Why do you not feed more frequently?” and “Do you think feeding more frequently will be healthy for your infant?” On each subsequent alternate-day visit, the mothers were asked if they had noticed any behavior changes in their infant, if they would continue to feed at the recommended frequency, and whether feeding more often influenced their breastfeeding practices. The study lasted for seven days. No food was provided by the study team.

Viscosity/energy density study

Although the mean energy density of the complementary foods in the weighed-intake studies was adequate, the most commonly offered food was plain parboiled rice, which may be difficult for young infants to consume with ease because of its consistency and viscosity. This study was carried out to determine if food or energy consumption at a meal could be augmented by decreasing viscosity by changing the recipe or adding amylase, increasing energy density by adding sugar or oil, or changing the food’s organoleptic characteristics. The infant’s consumption of four different formulations of *suji* (a wheat gruel commonly fed to infants) was compared with his or her intake of an ad lib diet (chosen by the mother) and finely mashed rice and dhal. Rice and dhal mashed into a fine paste was included as a treatment, because the mixture is commonly fed and has a better nutritional profile than most of the other local complementary foods. Hand-mashing of rice and dhal before feeding is practiced to some degree, but in most cases the rice is left in relatively large pieces in the final product, which may be difficult for younger infants to swallow.

We employed a repeated-measures crossover design in which each of 28 mothers was supplied with a different type of complementary food for a six-day period, skipped a day, and then began a new recipe. Each study participant used every recipe, and the order of recipes was randomized across all subjects. The study diets and their composition are shown in table 1.

On the first visit of each treatment period, the fieldworkers supplied the preweighed ingredients and demonstrated to the mothers how to prepare the food assigned that week. Enough food was provided to meet the age-specific energy requirements for infants receiving an average amount of breastmilk [1]. No ingredients were provided during the ad lib diet period, and the mothers were asked to follow their normal practices. For the suji with amylase diet, we used microbiologically produced α-amylase (α-amylase, Genencor International), which was provided to the mothers in premeasured vials sufficient for one meal each.

During each visit, the fieldworkers weighed the amount of food eaten in a single meal. The fieldworkers judged viscosity by observation and recorded it using the five-point scale previously described. On the final day of the study, the mother was asked how she and her infant liked the foods and how she would improve the recipes.

Micronutrient acceptability study

This study was undertaken to determine the acceptability and feasibility of using a liquid micronutrient supplement or a micronutrient-fortified fat-based

TABLE 1. Composition of study diets[a]

Diet	Ingredients	Energy density
Suji	40 g ground wheat + 10 g sugar + 350 g water	0.62 kcal/g (2.6 kJ/g)
Suji/oil	40 g ground wheat + 12 g oil + 350 g water	0.84 kcal/g (3.5 kJ/g)
Suji/sugar/oil	40 g ground wheat + 10 g sugar + 6 g oil + 350 g water	0.78 kcal/g (3.3 kJ/g)
Suji/amylase	40 g ground wheat + 10 g sugar + amylase + 200 g water	0.98 kcal/g (4.1 kJ/g)
Mashed rice with dhal		1.05 kcal/g (4.4 kJ/g)
Ad lib diet	Diet generally prepared for infants at home	Approximately 1.0 kcal/g (4.2 kJ/g)

a. Water quantities are the amounts prior to cooking, and the energy densities are estimated for the prepared food.

product to improve infant micronutrient intake. The liquid supplement used was a locally available multivitamin supplement called V-Plex (ACME Global), which is packaged in a tinted glass bottle with a plastic dropper built into the lid. Each bottle provides a 15-day supply of nutrients, as listed in appendix 1. V-Plex is commonly provided by local doctors and is available in the local market for 10 to 15 taka (approximately US$0.20). V-Plex was chosen because it was locally available and people were familiar with it. A liquid supplement that contained both vitamins and minerals was not available locally.

The fat-based product was supplied by the Institut de Recherche pour le Développement (Paris) and Nutriset (Malaunay, France). It resembled peanut butter in appearance and tasted like a dilute, oily peanut butter with a slightly gritty texture. Fortified fat-based foods have the advantage of being safe because children cannot eat large quantities, thus reducing the risk of accidental overdose, as could occur with liquid, powder, or pill supplements. Also, because the product is fat based, and thus free of water and oxygen, chemical reactions between vitamins and minerals are reduced. This improves the storage life and probably reduces the breakdown of vitamins. Nutriset reports very good acceptability by populations studied in Chad and Algeria [3, 4]. The composition of the product is detailed in Appendix 1. This product is not presently available for consumer purchase in Bangladesh.

On the first day of the study, a fieldworker explained the possible benefits of providing a micronutrient supplement. The study participants were supplied with the respective supplement and advised to give either 0.5 ml of the liquid supplement two times each day (n = 30, duration 7 days) or 30 g of the spread, divided into three 10-g portions and mixed with food each day (n = 44, duration 4 days). The mothers were advised to give the supplement only to the infant enrolled in the study. Each infant received only one type of supplement. On the first day of the fat-based product trial, a fieldworker observed the mother mix the spread with food and feed it to the infant. The same observer weighed the amount of food and fortified product consumed during the meal. Questions were asked to elicit the mother's opinions on using the supplement and whether the infant liked it. Possible responses included "Yes," "No," or "Do not know," plus the mother's explanation. Acceptance was assessed by disappearance of the samples and recall of the number of times the supplements were used.

Data analysis

Statistical analyses were performed with SAS-PC for Windows Version 6.10 (SAS Institute, Cary, NC, USA). Data on meal quantity (grams per meal) and frequency (number per day) were analyzed by repeated-measures analysis of variance (ANOVA). Post hoc pairwise comparisons between means were performed with Tukey's test. Data on viscosity/energy density were examined with a two-way ANOVA (SAS GLM LSM), with pairwise comparisons (grams per meal and kilocalories per meal) using Tukey's test. P values of less than 0.05 were considered to indicate statistical significance. Values are reported as means ± SD.

Results

Meal quantity study

Thirty mothers with infants between 6 and 12 months of age (mean, 9.5 ± 1.5 months) completed this study (table 2). On day 1, the initial quantity of food offered at the observed meal was 67 g, of which 40 g was consumed. The fieldworkers judged, by observation, that in 80% of the cases the meal ended because the infant appeared satiated, and in 20% of the cases the infant consumed all of the food that was prepared. After this first feeding attempt, the mothers were asked why they stopped feeding. They unanimously reported that the infant did not want any more food. Further explanations included "The baby does not want to eat more" (18 mothers); "The baby will spit food out if I force it into his or her mouth" (4 mothers); "I encouraged the baby and he or she refused" (4 mothers); "I plan to breastfeed" (1 mother); "The baby will vomit if I feed more" (1 mother); "The baby has taken the total serving" (1 mother); and "No particular reason" (1 mother).

The mothers were then asked to attempt to feed their children more. The mothers' comments on being asked to feed their infants this second time included "If it is good for the baby, I will try" (15 mothers); "The baby will vomit or cry if pressured to eat" (5 mothers); "The baby is full" (4 mothers); "I think I fed enough" (4 mothers); "The baby will only eat if food has sugar on it" (1 mother); and "Eating more will upset the baby and he or she will not take breastmilk" (1 mother).

During the second feeding, a mean of 9 ± 10 g (median, 5 g) of additional food was consumed. As the mothers fed their infants this second time, the fieldworkers observed that 20% of the infants (n = 6) still appeared to be hungry. These infants consumed a mean of 25 ± 14 g of food. The 80% of infants who were judged to be not hungry (satiated) consumed a mean of 5 ± 3 g of food during this second feeding.

Over the subsequent days of observation, the quantity of food offered to and consumed by the infants increased (table 2). The amounts consumed on days 5 and 7 were significantly greater than the amount consumed on day 1, and the duration of the meals was significantly longer on days 4 and 7 than on day 1. The viscosity decreased over the study period, but the

TABLE 2. Meal quantity study ($N = 30$): amounts offered and consumed and observations of feeding practices[a]

Measurement or observation	Day 1	Day 4	Day 7
Quantity of food offered (g)	67 ± 42	82 ± 33	95 ± 37
Quantity of food consumed (g)	40 ± 23^b	55 ± 28^c	64 ± 30^c
Reason mother stopped feeding			
Infant appeared satiated	80% ($n = 24$)	93% ($n = 28$)	97% ($n = 29$)
Infant finished all of the food	20% ($n = 6$)	7% ($n = 2$)	3% ($n = 1$)
Duration of meal (min)	6 ± 2^b	12 ± 2^c	13 ± 2^c
Viscosity of food[d]	3.7 ± 0.6	3.4 ± 0.7	3.1 ± 0.8
Infant's acceptance of food[e]	1.1 ± 0.3	1.2 ± 0.4	1.0 ± 0.2
Infant offered more to eat after satiated	70%	57%	70%
Meal frequency (previous day)	2.3 ± 0.9	2.4 ± 1.0	2.9 ± 0.8

a. Plus-minus values are means ± SD.
b, c. Values with different superscript letters within a row are significantly different ($p < 0.05$).
d. Scale ranges from 1 (like tea) to 4 (like cooked rice).
e. Scale ranges from 1 (very well liked) to 4 (did not like).

increase in the amount consumed was still significant after viscosity was controlled for. Infant acceptance of the food remained stable throughout the study. As determined by recall, the average meal frequency did not change significantly over the study period.

On days 4 and 7, all infants were judged by the fieldworkers to be hungry as the mother started to feed. The mothers' comments on days 4 and 7 about trying to increase meal size included "I try to feed but the baby doesn't want to eat more" (13 mothers); "If it is good for the baby I will try" (19 mothers); "The baby makes less disturbance when I feed more" (16 mothers); "The baby will vomit or cry if pressured to eat" (5 mothers); "Feeding more takes too much time" (2 mothers); "My baby is eating more; I am surprised" (2 mothers); and "The baby only wants breastmilk" (1 mother). The fieldworkers observed that on day 4, 93% of the mothers ended the meal because the infant appeared satiated; this proportion increased to 97% on day 7. In the remaining cases, the infants finished the entire portion offered.

On day 7, all of the mothers said they would continue to feed the increased amount fed during the study. Also on day 7, in response to the question "Has feeding more food affected your breastfeeding practices?", 63% of the mothers responded that the increase in meal quantity had decreased the infant's breastmilk consumption or the amount of time the infant spent at the breast, 3% (one mother) reported an increase in the infant's breastmilk consumption, and 34% reported that feeding more did not affect breastfeeding.

Meal frequency study

Thirty mothers with infants between 6 and 12 months of age (9.3 ± 1.5 months) completed the study (table 3). The reported daily meal frequency increased from 2.2 to 4.1 during the study. The number of meals reported on days 3, 5, and 7 was significantly greater than on day 1, and the number of meals on day 7 was greater than on days 3 and 5.

In response to the question "Why do you not feed more frequently?", the percentage of women who cited time constraints decreased from 47% to 33% during the study, the percentage citing lack of money decreased from 33% to 23%, and the percentage citing lack of food decreased from 13% to 7%. During 6 of the 120 visits, the observers noted that food was not available to feed the infant. The percentage who responded that the baby did not want to eat more meals than the current level increased from 37% to 47%, whereas the percentage of mothers who felt that the amount of breastmilk and other foods usually fed was enough for the infant decreased from 37% to 13%. As the study progressed, the mothers increasingly reported infant behavior changes. By the final day of the study, 33% reported less crying and 23% mentioned that the infant had more energy. On the first day of the study, 90% of the participants reported believing that feeding more frequently would benefit their infants' health by either preventing illness (77%) or improving growth (13%). This increased to 97% of the mothers by the final day of the study. At the end of the study, 29 of the 30 participants said they could continue to feed with the increased frequency practiced during the study.

On each day of observation, 27% of the study participants ($n = 8$) reported that feeding more frequently caused their infant to be less hungry and thus take less breastmilk. Six of these eight women gave the same response on each day of observation.

TABLE 3. Meal frequency study ($N = 30$): number of meals and responses to behavior-change questions

Question	Response	Day 1	Day 3	Day 5	Day 7
Complementary food meal frequency (mean ± SD)		2.2 ± 1.3[a]	3.1 ± 0.6[b]	3.4 ± 1.3[b]	4.1 ± 1.3[bc]
Why do you not feed more frequently?	Time constraints	47% ($n = 14$)			33% ($n = 10$)
	Baby does not want	37% ($n = 11$)			47% ($n = 14$)
	Current amount is enough	37% ($n = 11$)			13% ($n = 4$)
	Lack of money	33% ($n = 10$)			23% ($n = 7$)
	Not enough food	13% ($n = 4$)			7% ($n = 2$)
Have you noticed any behavior changes in your infant?	Infant cries less		10% ($n = 3$)	23% ($n = 7$)	33% ($n = 10$)
	Infant has more energy		7% ($n = 2$)	17% ($n = 5$)	23% ($n = 7$)
Do you think feeding more frequently will be healthy for your infant?	Yes	90% ($n = 27$)			97% ($n = 29$)
Will you continue to try to feed at the recommended frequency?	Yes		97% ($n = 29$)	100% ($n = 30$)	97% ($n = 29$)
Has feeding more food affected your breastfeeding practices?	Yes		27% ($n = 8$)	27% ($n = 8$)	27% ($n = 8$)

a,b. Values with different superscript letters within a row are significantly different ($p < 0.05$).

Viscosity/energy density study

Twenty-eight mothers with infants between 6 and 12 months of age completed this study. There was no difference in observed viscosity between suji, suji with oil, suji with sugar and oil, and suji with amylase, but mashed rice with dhal and the ad lib diet were significantly thicker than these four diets (table 4). The amounts consumed (in grams) did not vary significantly among suji, suji with oil, suji with sugar and oil, suji with amylase, and mashed rice with dhal, although infants consumed significantly more of suji and suji with amylase than of their ad lib diet. The ad lib diet was most commonly plain rice, but it also included rice with dhal; rice with sugar; and rice with vegetables, suji, and luta (rice-flour porridge). Energy intake from the meal was highest for suji with amylase, which had both a high energy density and a low viscosity. The second highest energy intake was from mashed rice with dhal, which had similarly high energy density but relatively high viscosity.

On the final day of the study, the participants were asked the questions shown in table 5. The women were also encouraged to provide open-ended remarks about the recipes. The ad lib diet and the rice and dhal diet were the favorites among both mothers (96% to 97%) and infants (89% to 90%). The mothers' comments on the ad lib diet included "My infant likes it because he or she is accustomed to it" ($n = 24$); "It is a family food so I do not have to prepare special foods" ($n = 19$); and "I can afford it" ($n = 6$). Comments on the rice and dhal diet included "It is a family food so I do not have to prepare special foods" ($n = 21$) and "My infant likes it because he or she is accustomed to it" ($n = 15$). Suji, suji with sugar and oil, and suji with amylase were liked by a large percentage of the mothers (82% to 89%) and infants (68% to 89%), although only half or less of the mothers said they would continue to feed these foods. Comments on suji included "It is easy to feed" ($n = 24$); "It is easy to prepare" ($n = 20$); and "My baby eats more of it than the usual diet" ($n = 14$). Comments on suji with sugar and oil included "I cannot afford this food" ($n = 9$); "It is quick to fill the stomach and satisfy the appetite" ($n = 8$); and "My baby eats more than usual" ($n = 7$). Comments on suji with amylase included "My baby eats more than usual" ($n = 23$); "It is easy to feed" ($n = 17$); "This food may be costly" ($n = 5$); and "It is not available in the market" ($n = 3$). Suji with oil was the least liked food, with only about half of the mothers reporting that their infants liked it. Comments on suji with oil included "I cannot afford this food" ($n = 9$); "It is quick to fill the stomach and satisfy the appetite" ($n = 8$); "My baby eats more than usual" ($n = 7$); and "I like it because it does not contain sugar which causes worms" ($n = 3$).

Interestingly, 79% ($n = 22$) of the study partici-

TABLE 4. Viscosity/energy density trial ($N = 28$): energy density, viscosity, and intake from various diets[a]

Diet	Energy density, kcal/g (kJ/g)[b]	Viscosity	Amount consumed per feeding, g[b]	Energy per feeding, kcal (kJ)[b]
Suji	0.62 (2.6)	2.7 ± 0.5[c]	82 ± 46[c]	51 ± 29[e] (213 ± 121)
Suji /oil	0.84 (3.5)	2.7 ± 0.5[c]	63 ± 49[cd]	53 ± 41[de] (222 ± 172)
Suji /sugar/oil	0.78 (3.3)	2.7 ± 0.5[c]	73 ± 47[cd]	57 ± 37[de] (239 ± 155)
Suji /amylase	0.98 (4.1)	2.9 ± 0.4[c]	80 ± 53[c]	79 ± 52[c] (331 ± 218)
Mashed rice with dhal	1.05 (4.4)	3.9 ± 0.2[d]	72 ± 37[cd]	75 ± 37[cd] (314 ± 155)
Ad lib diet	1.0 ± 0.3 (4.2)	3.6 ± 0.7[d]	54 ± 35[d]	54 ± 35[de] (226 ± 146)

a. Plus-minus values are means ± SD.
b. Values represent average intake from a single meal on three different days.
c–e. Values with different superscript letters within a column are significantly different ($p < 0.05$) .

TABLE 5. Viscosity/energy density trial ($N = 28$): percentage and number of mothers who answered yes to questions about food acceptance[a]

Question	Suji	Suji/oil	Suji/sugar/oil	Suji/amylase	Mashed rice with dhal	Ad lib
Do you like this food?	88 (23/26)	74 (20/27)	82 (23/28)	86 (24/28)	96 (26/27)	100 (27/27)
Does your infant like this food?	81 (21/26)	52 (14/27)	68 (19/28)	89 (25/28)	89 (24/27)	93 (25/27)
Did the infant finish the food?	23 (6/26)	11 (3/27)	11 (3/28)	18 (5/28)	7 (2/27)	22 (6/27)
Would you continue to feed this food?	50 (13/26)	52 (14/27)	32 (9/28)	39 (11/28)	93 (25/27)	96 (26/27)

a. The number of mothers varies because of missing data.

pants criticized these simple recipes and wanted to add spices, milk, eggs, dhal or rice powder, vegetables (pumpkin, greens, or potato), fruits (papaya, banana, or mango), fish, or meat to the foods to make them more wholesome.

Micronutrient acceptability study

Micronutrient liquid drops

Thirty mothers with infants between 6 and 12 months of age (mean age, 9.9 ± 1.8 months) completed this study. Twenty percent of mothers reported that they had given a similar supplement previously. We recommended that 0.5 ml of the drops be given twice each day. Mothers gave the drops a mean of 1.9 ± 0.3 times per day, providing a total of 0.8 ± 0.2 ml/day, indicating a high degree of adherence to the suggested regimen.

On the first day of the study, responding to the question "How do you feel about using a micronutrient supplement?", 90% of the mothers commented that they believed it would make their infants healthy. The remaining 10% did not associate vitamin supplementation with any health outcomes. Further comments included "The vitamins will make my baby stronger" (13%); "The vitamins will help my baby grow properly" (10%); "The vitamins will help prevent disease" (10%); and "The vitamins will increase my baby's appetite" (3%). There was some confusion because some of the mothers thought the vitamin was a medicine. We stressed that vitamins like those in the supplement are best acquired from food. Mothers entertained this idea but stated that they could not afford fruits, eggs, fish, and meat.

On the last day of the study, all of the mothers responded that they would be willing to give the drops on a daily basis, but this number dropped to 77% when they were asked if they were willing to pay for the supplement. All of the mothers thought the supplement was healthy for the infant and said giving the supplement was a practice they would recommend to other women.

Micronutrient-fortified fat-based product

Forty-four mothers with infants between 6 and 13 months of age (10.2 ± 1.6 months) completed this study. None of the mothers was already giving a supplement to her infant. On day 1, the mothers mixed 10 g of the product with 34 ± 22 g of rice. The infants consumed a mean of 27 ± 17 g of this preparation. Forty-one percent of the infants consumed 80% or more of the mixture offered, and 21% consumed 90% or more. The mothers' comments about the product included "Smells good like nuts, soybeans, or Horlicks (a malted milk drink)" (27%); "It is oily; the baby will not eat it, but I will try to feed it" (25%); "Similar to ghee or halua, very good" (23%); "It is not sweet, but

I will try to feed it" (9%); "The baby will not eat it" (9%); and "Smells bad" (7%).

Based on the disappearance of the fat-based product during the four days of study, the average amount of the product given daily was 26 ± 9 g (of the recommended 30 g) over an average of 2.3 ± 0.8 feeds. At the end of the intervention, 84% of the mothers said that their infants liked the product. When asked whether mixing the product with food affected the amount of food the infant ate, 37% of the mothers responded that the infant took more food, 34% said the infant took less food, and 29% reported no difference.

At the end of the intervention, all of the mothers felt that the product was healthy for their infants and said they would recommend using the product to other mothers. However, 23% of the mothers responded that they would not want to feed it on a daily basis, either because the baby did not want it (7%) or because they did not think they would be able to afford it (based on a cost estimate similar to that of the liquid supplement) (16%). Forty-one percent said they would be willing to buy the spread for their infant if it was similar in cost to the liquid supplement.

Discussion

Summaries and interpretations

In the behavioral trial intended to increase meal quantity, the mothers increased the amount they fed their infants at a meal by 60%, and they doubled the amount of time spent feeding at that meal. Interpretation of these results is limited, because we measured intake from only one meal on each day of observation and thus do not know the effect on breastmilk intake or total daily energy and nutrient consumption. At the end of the study, all participants said that they had fed their infants more complementary food during the study period, but 63% felt that feeding more had decreased the infant's breastmilk consumption. This potential tradeoff might result in diminished returns if the quality of complementary food is poor.

In the meal frequency trial, the study participants increased the mean number of times per day they reportedly fed their infants from 2.2 ± 1.3 to 4.1 ± 1.3. The majority of the participants felt that feeding more frequently was healthy for their infants, and at the end of the study all but one of the mothers said they would continue to feed with the increased frequency. However, 27% of the mothers felt that their infants took less breastmilk due to the increase in meal frequency. This is difficult to interpret, because we do not know whether the child actually consumed less or simply spent less time at the breast. The short duration of this study is a limitation, leaving the long-term effects uncertain. Further, we do not know how the increase in the number of meals affected the quantity of complementary foods served or consumed. The effects of feeding frequency and energy density were examined by Brown et al. [5] in a clinical setting using foods with varying energy densities fed to nonbreastfed children (6–18 months of age). The study demonstrated a 16% increase in daily energy intake when the number of meals increased from three to four, and a 7% increase when the number increased from four to five, while controlling for energy density. Thus, increasing meal frequency may increase food consumption by nonbreastfed children. The applicability of their results to breastfed children is unknown.

In the viscosity/energy density trials, the mothers were able to increase their infants' energy consumption per meal, as compared with the ad lib diet, by decreasing the viscosity of rice porridge with α-amylase and by feeding hand-mashed rice and dhal. Other studies examining the effects on energy consumption of food liquefaction with amylase have found similar results. Bennett et al. [6] demonstrated greater daily energy intakes among 8- to-17-month-old children from liquefied diets with energy densities of 1.0 to 1.8 kcal/g (4.2–7.5 kJ/g) than from diets with a high viscosity and the same energy density, or with low viscosity and an energy density of 0.6 kcal/g (2.5 kJ/g). This is consistent with a recent review of studies that concluded that benefits from liquefaction are most likely to occur when diets have an energy density greater than 1.0 kcal/g (4.2 kJ/g) [1]. In addition, it has been theorized that because energy-dense food will permit less frequent meals of a smaller volume, the displacement of breastmilk may be minimized [1]. Hand-mashed rice with dhal was well accepted by the mothers, because it was a commonly used and thus familiar food. A major limitation of this study was that intake was measured at only one meal each day. Further, the six-day duration of each treatment may not have permitted the infants to become fully accustomed to the new diet, although the recipes we used were only minor variations of local complementary foods. It is possible that a longer exposure to the recipes would lead to further changes in energy consumption from the study diets.

It is difficult to satisfy theoretical requirements of some nutrients, particularly iron, zinc, and calcium, unless substantial amounts of animal-source foods are fed to infants or micronutrient supplements are provided [1]. Possible ways of improving micronutrient intake are by including locally available micronutrient-rich foods in the children's diets, fortifying local foods (by adding micronutrients at the central, community, or household level), or giving supplements directly to children. In view of the fact that increases in the consumption of animal-source foods are unlikely to occur in the near future in Bangladesh, and no plans are currently under way to fortify commonly consumed foods, we decided to test the acceptability and feasibility of using a liquid micronutrient supplement and a micronutrient-fortified fat-based product. Both supplements were well accepted and used correctly at the household level for the duration of the study. Limitations of this study were the short time span and lack of direct observation of consumption. The ability and willingness of women to maintain the use of a supplement over a long time period will need further investigation, but the majority of mothers in this study said they were willing to feed a supplement daily. Interestingly, most of the mothers commented that they would prefer food instead of the supplement and that they would not need the supplement if they could provide proper food. Such local wisdom should be complemented with public health advice on methods to achieve optimal nutrition. Ideally, any project or program that advocates or administers nutritional supplements should also promote recommendations that encourage a population to satisfy its nutritional needs through appropriate dietary practices and assist in the development of social and economic structures that will make this possible.

Although the participants in this study responded positively to the educational messages, the questions remain whether the changes were sufficient to achieve adequate energy intake, and what are the potential tradeoffs or problems that may arise due to the adoption of these practices. The mean recommended energy from complementary food for 6- to 11-month-olds has been estimated to be about 250 kcal (1,047 kJ) for those receiving average levels of breastmilk and 46 kcal (193 kJ) for those receiving high levels of breastmilk [2]. In the weighed-intake studies, we observed average to high intakes of breastmilk in this population. By combining the potential increase from the meal frequency and meal quantity studies (four meals/day at 64 g each and an energy density of 1.1 kcal/g [4.6 kJ/g], the median energy density observed during the weighed-intake studies), we can estimate a potential intake from complementary food of about 260 kcal/day (1,088 kJ). This may be an overestimate due to tradeoffs between increases in meal quantity and frequency. Nevertheless, this potential intake meets the needs of infants with average breastmilk intake, and is approximately twice the present intake of energy from complementary food observed in the weighed-intake studies. Larger increases in energy intake might be realized if we consider effects due to increasing the diet's energy density. However, these estimations might not be generalizable to a large-scale intervention, since the frequent home visits in this study may have enhanced adherence to the recommendations.

On the other hand, it is possible that interventions such as these might lead to a displacement of breastmilk as a result of the infant's appetite being satisfied by complementary foods, the mother's feeling she does not need to breastfeed as often or as long because she has fed other food, or the mother's not having as much time to breastfeed due to the increased time spent preparing and feeding complementary foods. There is limited information on the effects of complementary food intake on breastmilk intake. Drewett et al. [7] followed 60 Thai infants for the first year of life and measured breastmilk and complementary food intake at several time points. They concluded that energy from complementary food displaces breastmilk and that the magnitude of the effect declines progressively with age. For example, they found that at the age of 6 months, each additional 1 kcal (4.2 kJ) from complementary food was associated with a decrease of 0.57 kcal (2.4 kJ) from breastmilk, whereas at 12 months each additional 1.0 kcal was associated with a decrease of only 0.28 kcal (1.2 kJ) from breastmilk. Increased meal frequency has also been associated with a decrease in breastfeeding frequency and time spent nursing [8]. In the weighed-intake study, we observed that an increase of 1 kcal (4.2 kJ) from complementary food was associated with a decrease of 0.46 kcal (1.9 kJ) from breastmilk. Thus, if we assume that the educational interventions could increase complementary food intake by 130 kcal (544 kJ), then total energy intake may only increase by 70 kcal (293 kJ). It is also important to consider other potential risks associated with increasing complementary food quantity or meal frequency, depending on demographic or individual characteristics. For example, increases in meal frequency may lead to an increased risk of illness from food-borne pathogens if mothers who lack refrigeration or adequate fuel for cooking or reheating decide to hold food over from one meal to the next instead of freshly preparing it. In populations where food availability is sporadic, a greater dependence on complementary foods (as compared with a high percentage of energy from breastmilk) might make an infant more vulnerable to a severe reduction in intake during transitory food shortages.

Conclusions

Improving infant health in less-industrialized countries will require more than making appropriate food and health care available. Caregivers must also understand and follow recommended infant-feeding practices. Although general recommendations have been published on breastfeeding practices, infant nutrient needs, meal frequency, complementary food energy density, and other caregiving needs [9], these recommendations need to be adapted according to locally obtained empirical data on current feeding practices. The present studies were designed to assess current complementary feeding practices in Bangladesh quickly and inexpensively. In the first stage of this project, we quantitatively assessed the dietary intake and feeding practices of rural Bangladeshi infants. Based on this assessment, changes in current feeding practices that might improve infant nutrition were identified. These behavior-change trials were then conducted to determine the ability and willingness of caregivers to adopt the suggested changes. The fieldwork for both the quantitative assessment and the behavior-change trials, including the training of villagers as fieldworkers, data collection, and data entry, was completed in 4.5 months at relatively low cost. We were able to carry out this wide-ranging assessment within this time frame by using short-term interventions and both qualitative and quantitative research methods. As resources permitted, quantitative data were collected to assess the effects and acceptance of behavior changes objectively. Qualitative information was then elicited to illuminate caregivers' feelings about the behavior changes and assess the likelihood that the changes would be sustained. The behavior-change trials reported herein were intended to assess the flexibility of feeding practices in rural Bangladesh. The results will be useful in planning longer-term trials to develop programmatic recommendations to resolve the previously identified shortfalls in energy and micronutrients.

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Appendix 1. Composition of micronutrient supplements

Composition of liquid supplement (VitaPlex)

1 ml contains the following ingredients:

Vitamin A	5,000 IU
Vitamin D	640 IU
Vitamin C	50 mg
Thiamine	1.6 mg
Riboflavin	1.37 mg
Pyridoxine	1 mg
Niacin	10 mg
D-Panthenol	5 mg

Composition of fat-based product (ration for 1 day)

Defatted soya flour	20%
Vegetable fat	40%
Sugar	17.8%
Lactoserum	20%
Lipid (vegetable)	12 g
Protein (soybean)	4 g
Vitamin-mineral complex	2.2%
Vitamin A retinol equivalents (RE)	350 μg
Folate	50 μg
Niacin	4 mg
Riboflavin	0.4 mg
Thiamine	0.2 mg
Vitamin B_6	0.3 mg
Vitamin B_{12}	0.4 μg
Vitamin C	25 mg
Vitamin D	7 μg
Vitamin E	4 mg α-tocopherol equivalents (TE)
Calcium	250 mg
Copper	0.5 mg
Iodine	60 μg
Iron	11 mg
Magnesium	75 mg
Phosphorus	175 mg
Potassium	300 mg
Selenium	5 μg
Sodium	160 mg
Zinc	1 mg

Ecuadorian Andean women's nutrition varies with age and socioeconomic status

Barbara Macdonald, Timothy Johns, Katherine Gray-Donald, and Olivier Receveur

Abstract

An agricultural project in Highland Ecuador provided a model context to better understand the nutrition of rural women. The adequacy of women's nutrition and the strength of associations with age and socioeconomic status were studied in 104 rural households over four rounds (two seasons) during the 1995–1996 agricultural year using a cross-sectional with repeated-measures design. Women were at high risk for micronutrient deficiencies (calcium, iron, riboflavin, and vitamin B_{12}) due to low intakes of animal products. Two distinct constructs representing socioeconomic status were identified: modern lifestyle and farming wealth. In multivariate models, farming wealth was associated with quality of women's diet (animal protein adjusted for energy, p *= 0.01). Diet quality, in turn, was positively associated with anthropometric status (*p *= 0.02). Women over the age of 50 weighed approximately 3.7 kg less than younger women and consumed less energy (300 kcal) and micronutrients (*p *< 0.05). Age was positively associated with respiratory morbidity (*p *= 0.01). These findings, while directly relevant to a specific context, suggest the need for cross-cultural studies to identify the extent of, and factors contributing to, the risk of nutritional inadequacy in postreproductive women in developing countries.*

Key words: Ecuador, Andean, nutrition, micronutrients, women, socioeconomic status

Introduction

The harsh environmental and economic conditions faced by small-scale farming households in developing countries often lead to marked food insecurity and malnutrition.The impacts on children are well documented, with inadequate nutrient intake, high rates of infant morbidity and mortality, and compromised linear growth among the outcomes reported. Less well studied is the nutritional status of rural adults, particularly those beyond their reproductive years, as they are frequently excluded by sampling protocols focused on young children. Women, in particular, are at risk, as their multiple roles exact a heavy nutritional toll. Gender biases in food distribution and access to health services compound these strains [1, 2] and may become more pronounced as women move beyond their reproductive years. Valuable insights into the true extent of rural poverty and food insecurity may be gained by better documenting the nutritional status of women.

An agricultural project in Highland Ecuador provided a model context to study the nutrition of rural women. Data were collected in 1995 and 1996 as part of a larger study of the impact of the reintroduction of an indigenous crop (quinoa) to the farming system. Drought, freezing temperatures, soil erosion, and malnutrition characterize this region. Among children, 52% of those under five years of age are stunted, and approximately 25% suffer from riboflavin and iron deficiencies [3, 4].

The specific objectives of this study were to establish

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This study was conducted at McGill University and formed part of the corresponding author's doctoral research.

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the adequacy of diet and anthropometric status among Ecuadorian women residing in an Andean rural setting, including those of advanced age; and to apply multivariate analyses and determine the strength of associations between socioeconomic status and women's nutritional status in this population.

Materials and methods

Study design, sampling, and research team

Anthropometry, repeated 24-hour dietary recalls, and agricultural and socioeconomic surveys were conducted in the province of Chimborazo (2,400 to 4,000 m above sea level) over four study rounds timed to cover the pre- and post-quinoa-harvest seasons. In order to participate in the study, households had to maintain their principal residence in the community and own less than 10 hectares of land. The sample comprised all quinoa producers in three communities as well as a randomly selected group of non-quinoa producers. Because of the small size of the communities, sampling resulted in a near-census of households. Only one woman from each household was studied. The nonresponse rate was 14%, and the final sample consisted of 104 households. Of those 104 households, 91 provided dietary data over both seasons (12.5% were lost to follow-up), and 63 provided anthropometric data. There were no differences in level of education or socioeconomic status between women who completed the study and those lost to follow-up (data not shown).

The research team consisted of four indigenous women from the region, a local university-trained nutritionist, and the corresponding author. All data were collected in the local language, Quichua, and then translated into Spanish.

Dietary assessment

Dietary intake was assessed with four nonconsecutive 24-hour recalls covering both seasons. We asked the female head of the household to recall all foods and beverages consumed during the previous day. Common-pot eating predominates in this region, so research assistants obtained full ingredient lists including portion sizes from the subjects. For meals consumed away from home, the subjects recalled as many ingredients as possible, and standardized recipes were applied. Serving sizes were estimated with standard-sized cups, bowls, and spoons, and local foods were weighed to improve the precision of the estimates.

In addition to absolute nutrient intakes, the ratio of energy intake to basal metabolic rate (physical activity level or PAL) was calculated to estimate energy adequacy and to determine the extent of under- or overreporting in the dietary intake data [5, 6]. The basal metabolic rate was calculated for each woman applying age and weight-specific equations presented by the Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU) [5]. If a woman's actual weight was unavailable, her weight was estimated by taking the average weight of women of the same age.

Anthropometric methods

Anthropometric measurements included height, weight, mid-upper-arm circumference (MUAC), and triceps skinfold thickness. Arm fat area (AFA) and arm muscle area (AMA) were calculated according to formulas in Frisancho [7]. Shorr height measuring boards (Shorr Corporation, Olney, MD, USA), a Seca electronic balance (Seca Corporation, Columbia, MD, USA), nonstretchable plastic measuring tapes for arm circumference, and Lange calipers (Cambridge Scientific, Cambridge, MA, USA) were utilized. All measurements were made in triplicate in accordance with standardized methods [8, 9]. The subjects removed the majority of their clothing, with the remaining items recorded and sample items representing jewellery and clothing weighed and subtracted from the measures.

Household socioeconomic and health variables

Household socioeconomic and health variables were measured with gender-disaggregated questionnaires and direct observation of assets both at baseline (preharvest) and postharvest. The survey tools were pretested with 20 families not participating in the study. Male respondents provided data on age, sex, formal and informal education of household members, occupation, water supply, human waste and garbage disposal, ownership of durable goods, landholdings, and land in cultivation. The female head of the household provided details on her occupation, morbidity, and household use of health services. Housing characteristics, latrine ownership, and water supply were determined by direct observation.

Morbidity was determined by recall. The women reported the occurrence, severity, and duration of five symptoms characteristic of gastrointestinal or respiratory illness during the previous two weeks. These symptoms were diarrhea, fever, vomiting, cough, and difficulty breathing.

Data entry and analysis

Questionnaire and anthropometric data were entered by a single clerk into the Epi Info 6 program, Version 6.02 [10]. All data were reviewed twice to ensure correct coding. Dietary recall data were entered similarly and analyzed with an Ecuadorian food-composition database created with the Worldfood Dietary Assessment System, Version 2 [11]. Food-composition data were gathered from Ecuadorian [12] and Mexican [11] tables and from the scientific literature for Andean crop nutrient composition [13–16].

Data analysis was completed with the SAS statistical program (Version 6.12) [17] with variables first tested for normality with SAS univariate and normal probability plot procedures. Means, medians, and frequencies were generated for all data as appropriate given the distribution. Pearson and Spearman correlations tested bivariate associations among independent variables and between independent and dependent variables.

Principal-components analysis conducted with PROC FACTOR (principal axis) was used to construct measures of socioeconomic status [18]. Principal-component scores were then included as predictors in multivariate analyses with diet quantity (energy), diet quality (animal-protein intake adjusted for energy), and anthropometric status as dependent variables.

Animal protein was chosen as the diet quality marker, because these women were shown to consume diets characterized by low intakes of micronutrients (especially riboflavin, vitamin B_{12}, calcium, and iron) that are in their most bioavailable forms in animal products. Spearman correlations were calculated between animal protein (in grams) and intakes of these micronutrients and were significant for vitamin A ($r = 0.45$, $p < 0.01$), vitamin B_{12} ($r = 0.96$, $p < 0.01$), iron ($r = 0.66$, $p = 0.01$), riboflavin ($r = 0.62$, $p < 0.01$), and calcium ($r = 0.60$, $p < 0.01$). Multivariate analyses were conducted with PROC REG in SAS.

Results

Dietary intake

Table 1 presents nutrient intakes for Ecuadorian women, averaged over four days. The average energy intake for the group was 2,656 kcal/day, which, when divided by these women's estimated basal metabolic rate, yields a PAL of 2.15. The reported intakes appear to be valid, as the mean PAL is approximately 5% to 10% above that calculated by Leonard et al. [19] employing heart-rate monitoring in Ecuador (PAL, 1.96) and Kashiwazaki et al. [20] employing doubly-labeled water in Bolivia (PAL, 2.04). Thus, energy intake appears adequate for this group.

When the dietary adequacy of protein, zinc, iron, vitamin B_{12}, folate, niacin, riboflavin, and thiamine was tested with probability analysis [21], notable insufficiencies were found in the intakes of riboflavin (prevalence of inadequate intake, 89%), vitamin B_{12} (28%), iron (58%), and niacin (11%). These inadequacies reflect low consumption of animal products, which contributed just 6.4% of energy. These women also consumed a large amount of phytates (2,370 ± 60 mg/day), which reduced the bioavailability of zinc and iron. The phytate-zinc molar ratio was 21, a level expected to reduce the availability of zinc to just 15% [22]. Calcium intake was below reference values, whereas folate, thiamine, and vitamin C intakes were largely sufficient.

To determine whether dietary intake was different

TABLE 1. Energy, protein, and micronutrient intakes (mean ± SD) for Chimborazo women

Variable	Total sample ($n = 91$)	FAO/WHO reference values	Women < 50 yr ($n = 65$)	Women ≥ 50 yr ($n = 26$)
Energy (kcal/day)	2,656 ± 656	2,465	2,741 ± 668	2,441 ± 583*
Estimated BMR	1,235 ± 65	N/A	1,252 ± 51	1,192 ± 75**
Intake:BMR ratio	2.15 ± 0.52	N/A	2.19 ± 0.54	2.04 ± 0.47
Protein (g)	72.1 ± 22.0	36.5	75.4 ± 22.1	64.05 ± 19.72*
Niacin (mg)	19.2 ± 6.0	17.3	19.6 ± 6.4	18.3 ± 5.0
Riboflavin (mg)	1.0 ± 0.3	1.44	1.0 ± 0.3	0.9 ± 0.3*
Thiamine (mg)	1.8 ± 0.6	1.04	1.9 ± 0.6	1.7 ± 0.5
Folate (μg)	253 ± 102	151[a]	254 ± 99	248 ± 112
Vitamin B12 (μg)	1.3 ± 1.0	1.0	1.4 ± 1.0	1.0 ± 0.9*
Vitamin C (mg)	126 ± 45	30	128 ± 47	121 ± 42
Vitamin A (RE)	737 ± 621	500[a]	752 ± 625	699 ± 621
Calcium (mg)	329 ± 137	450	346 ± 138	288 ± 126
Iron (mg)	14.2 ± 4.4	12.5/9.5[b]	14.6 ± 4.4	12.9 ± 4.1
Zinc (mg)	11.1 ± 3.3	N/A	11.6 ± 3.3	9.9 ± 3.0*
Bioavailable zinc (mg)	1.67 ± 0.50	0.87[c]	1.74 ± 0.49	1.49 ± 0.47*

BMR, Basal metabolic rate; N/A, not available; RE, retinol equivalents.
a. Safe level.
b. Basal requirements: 12.5 mg for menstruating women, 9.5 mg for postmenopausal women.
c. Normative requirement.
*$p \le 0.05$, **$p \le 0.001$.

among women in their postreproductive years, we calculated the mean nutrient intakes for women below and above 50 years of age. Estimated energy and protein intakes differed between the two age groups, with the younger women consuming approximately 300 kcal/day more than the older women. The older women maintained an acceptable PAL at this lower intake (2.04), but only because their weight was lower. In line with the energy results, older women had lower absolute intakes of riboflavin, vitamin B_{12}, calcium (p = 0.07), and zinc. The results of age group tests repeated for micronutrient intakes adjusted for energy were not significant, indicating that older women ate less food, but not different foods, than their younger counterparts.

Anthropometric status

Table 2 presents data on mean height, weight, and body mass index (BMI) according to age category. Six pregnant or lactating women were excluded from the analysis, resulting in a sample size of 57 with a mean age of 41.5 years.

At first glance, these values reflect the typical short Andean physique [19, 23, 24]. The mean heights for all age categories fall below 150 cm, but at an average of 22.52, the BMIs for these women indicate maintenance of a "normal" weight for that height.

Classification of BMI distribution according to the World Health Organization (WHO) criteria [25] showed little evidence of protein/energy stress, with 80% of the sample falling within the normal range of 18.5 to 25. Only one woman (aged 55 years) out of 57 (1.8%) was "thin"; in addition, with no BMI found to be higher than 30, obesity was a minimal problem. Interpretation requires caution, however, as South American populations possess short legs relative to body length and may have higher BMIs for weight than European and Indo-Mediterranean populations [25]. Sitting height was not measured, disallowing corrections to BMI based on the Cormic Index [26].

Consistent with the dietary data, older women (50 years and older) weighed 3.7 kg less than younger women and had a lower BMI. MUAC, triceps skinfold thickness, and the calculated indices of AFA and AMA [7] presented in table 3 aid in pinpointing the source of weight differences. Although the data cannot be extrapolated to account for the composition of the entire body, arm fat stores were lower in the women over 50.

TABLE 2. Height, weight, and body mass index (BMI) of Chimborazo women (mean ± SD)

Age (yr)	n	Height (m)	Weight (kg)	BMI (kg/m^2)
20–29	10	1.48 ± 0.04	49.4 ± 5.5^a	22.6 ± 1.6^{ab}
30–39	18	1.48 ± 0.07	50.8 ± 6.7^a	23.1 ± 2.2^b
40–49	11	1.44 ± 0.05	49.4 ± 6.3^a	23.6 ± 2.3^b
≥ 50	18	1.47 ± 0.05	45.7 ± 5.3^b	21.2 ± 2.0^a
Total	57	1.47 ± 0.05	48.7 ± 6.2	22.5 ± 2.2

a,b. Means with different superscript letters are significantly different ($p \leq 0.05$).

Morbidity

Spearman correlations showed a positive association between age and the number of days ill with respiratory symptoms ($r = 0.36$, $p = 0.01$), indicating increased respiratory morbidity among the older women. Close to one-half of the women studied reported days ill with respiratory symptoms, and Spearman correlations showed a negative association with MUAC ($r = -0.27$, $p = 0.05$). Vomiting and diarrhea failed to correlate with any of the anthropometric indicators.

Socioeconomic effects

Principal-components analysis was used to reduce redundancy among the many socioeconomic variables measured. This technique reduces several correlated variables to a few independent components that account for a significant proportion of the variation in the original data set [27].

Table 4 presents the two socioeconomic components identified and the individual factor loadings for the 13 socioeconomic variables analyzed. Eigenvalues, the scree test, and interpretability were applied in the selection of components to be retained. Factor load-

TABLE 3. Mid-upper-arm measurements and related indices of Chimborazo women (mean ± SD)

Age (yr)	n^a	Triceps skinfold thickness (mm)	MUAC (cm)	AMA (cm^2)	AFA (cm^2)
20–29	9	10.1 ± 2.2^b	25.7 ± 1.2^b	34.0 ± 4.8	12.1 ± 2.5^b
30–39	17	12.4 ± 3.1^c	26.4 ± 2.1^b	34.2 ± 7.0	15.3 ± 4.0^c
40–49	10	11.5 ± 3.4^{bc}	25.0 ± 2.5^{bc}	30.2 ± 7.6	13.5 ± 4.4^{bc}
≥ 50	17	8.4 ± 3.0^{d**}	24.3 ± 2.4^{c*}	31.2 ± 6.1	9.9 ± 3.8^{d**}
Total	53	10.6 ± 3.4	25.4 ± 2.3	32.4 ± 6.6	12.7 ± 4.3

MUAC, Mid-upper-arm circumference; AMA, arm muscle area; AFA, arm fat area.

a. The sample size was reduced from 57 to 53 because four women refused to have arm measurements made.

b–d. Means with different superscript letters are significantly different (*$p \leq 0.05$, **$p \leq 0.01$).

ings are bivariate correlations between the variable and the component. A factor loading greater than 0.40 is deemed large. An eigenvalue is the amount of original variance in the data accounted for by a component. A scree test plots eigenvalues to identify natural separations between components with high and low eigenvalues. Principal-components analysis standardizes variables (mean = 0, standard deviation = 1). A component with an eigenvalue <1 accounts for less variance than an individual variable and is normally not retained for further analysis [27].

Although four components had eigenvalues greater than 1 and jointly explained 66% of the variance, the scree appeared to begin after the second component, with the third and fourth components difficult to interpret. Thus, only the first two components, which jointly explained 50% of the variance in the original variables, were retained.

Nine of the 13 variables had large loadings for component 1, which accounted for 30.6% of the variance. These variables are marked with asterisks in table 4 and include possession of small durable goods and improved housing materials, forming a construct that may be described as "modern lifestyle" [28, 29]. Component 2 represents the construct of "farming wealth" and accounted for 16.7% of the variance in the original variables. Variables with large loadings for this component included land ownership, land in cultivation during the study year, and small livestock. When the principal-components analysis was performed, some variables originally measured were dropped because they did not load on the retained components or they loaded on both components. These included work migration patterns and ownership of radios, vehicles, back-pack sprayers, sheep, swine, horses, and mules. Variables that do not load clearly on components are often removed from an analysis [27]. Total income loaded equally on both components and was therefore dropped.

TABLE 4. Principal-components analysis of socioeconomic markers in the Ecuadorian Andes ($N = 89$)

Variable	Component 1 "modern lifestyle"	Component 2 "farming wealth"
Roof material (straw, zinc, eternit)	39*	–18
Floor material (earth, wood, cement)	66*	–14
Wall material (adobe, cement/brick)	48*	–30
Stoves (no.)	70*	9
Furniture (no. of pieces)	80*	10
Bicycles (no.)	63*	24
Stereos (no.)	65*	–9
Television sets (no.)	67*	–3
Blenders (no.)	80*	0
Land (hectares owned)	–15	78*
Land in cultivation 1995–96 (hectares)	–4	85*
Fowl (no. owned)	26	52*
Guinea pigs (no. owned)	17	59*
Eigenvalue	3.985	2.161
Cumulative variance explained	0.306	0.473

* Large factor loading.

Bivariate correlations calculated between these components and age and education demonstrated significant potential for confounding (data not shown). Specifically, women's age was negatively associated with both education ($r = –0.56, p < 0.001$) and modern lifestyle ($r = –0.29$, $p = 0.006$). An inverse relationship between age and literacy has been reported previously in these communities [30] and may be due to a secular trend in access to education. Therefore, to reduce collinearity, education was excluded in multivariate models as it is important to retain age in nutritional analyses.

Table 5 presents models demonstrating the relationships between the socioeconomic constructs (adjusted for age) and women's nutrition. The socioeconomic variables, especially farming wealth, were positively associated with diet quality (animal-protein intake adjusted for energy), but not with diet quantity (energy). For anthropometry, the only significant model was for AFA, with a trend towards larger fat stores with increased modern lifestyle.

The question remains whether diet quality is related to anthropometric status. Multivariate models presented in table 6 demonstrate that animal protein (adjusted for energy) is indeed a predictor of BMI, MUAC, and AFA when adjusted for age. Adjusted for age, each additional gram of animal protein per 1,000 kcal consumed was associated with a 0.19 kg/m^2 increase in BMI, a 0.25 cm increase in MUAC, and a 35.8 mm^2 increase in AFA. In addition, of particular interest to nutritionists, when the components were included in these models, the effect of animal protein remained significant, while the socioeconomic components did not (data not shown). Therefore, animal-protein intake is not likely to be acting merely as a proxy for socioeconomic status in this population.

Discussion

Despite the pivotal role played by women in household production and reproduction, their nutritional status has been largely neglected as a serious topic of study.

The high probabilities of inadequate micronutrient intakes among rural Ecuadorian women reported here illustrate the situation facing women and children worldwide. Micronutrient deficiencies place women at

TABLE 5. Multivariate models of Chimborazo women's nutrition

Variable	Energy (kcal) (n = 85[a])		Animal protein (g/1,000 kcal) (n = 85)		AFA (mm^2) (n = 47)	
	β-Coefficient	Prob > T	β-Coefficient	Prob > T	β-Coefficient	Prob > T
Intercept	2,914.96	< 0.01	7.59	< 0.01	1,557.29	< 0.01
Woman's age (yr)	–8.20	0.09	–0.11	0.10	–7.53	0.11
Modern lifestyle (standardized)	27.70	0.70	1.99	0.11	137.30	0.07
Farming wealth (standardized)	33.97	0.59	2.62	0.01	45.59	0.45
p value	0.30		< 0.01		0.04	
R^2	0.04		0.14		0.17	

AFA, Arm fat area.
a. The sample size was reduced because four households did not have an adult female.

TABLE 6. Multivariate models demonstrating the effect of diet quality on Chimborazo women's anthropometric status

Variable	BMI (kg/m^2) (n = 51)		MUAC (cm) (n = 47)		AFA (mm^2) (n = 47)	
	β-Coefficient	Prob > T	β-Coefficient	Prob > T	β-Coefficient	Prob > T
Intercept	22.94	< 0.01	24.68	< 0.01	1,409.47	< 0.01
Woman's age (yr)	–0.04	0.09	–0.02	0.39	–8.86	0.05
Animal protein (g/1,000 kcal)	0.19	0.03	0.25	0.01	35.79	0.04
p value	0.02		0.02		0.01	
R^2	0.16		0.17		0.18	

BMI, Body mass index; MUAC, mid-upper-arm circumference; AFA, arm fat area.

high risk of anemias, compromised immunocompetence, and, for those of childbearing age, maternal mortality [31]. High rates of micronutrient deficiencies among women also place infants at risk both pre- and postpartum, and the lethargy associated with anemias and mild energy insufficiency may compromise maternal caring capacity and labor productivity.

Although a broad literature now details inadequate micronutrient intakes among Latin American children, including Ecuadorians [4, 32–35], similar high-quality data describing women's intake in the Andes are limited. In fact, only Kim et al. [33] and Berti et al. [32] provide information for Bolivia and Ecuador, respectively. Kim et al. [33] observed low intakes of calcium and vitamin A relative to Bolivian recommended intakes. Similar to our findings, Berti et al. [32] reported inadequate intakes of calcium, vitamin A, riboflavin, and vitamin B_{12}. More recently, in a Mexican sample, more than one-third of women of reproductive age had low ferritin, hemoglobin, and plasma B_{12} values [36].

A number of the micronutrients found to be lacking in the diet (riboflavin, iron, calcium, and vitamin B_{12}) are found in the highest amounts and most bioavailable form in animal products. The low intake of these foods (approximately 6% of total energy) among this population confirms other reports from Ecuador, where the contribution of animal products to total energy intake ranged from 5% to 7.7% [37, 38]. Animal-product intake is a significant predictor of child size in Ecuador* and Mexico [39]. The demonstrated association between animal-protein intake (adjusted for energy and socioeconomic status) and increased anthropometric status in adult women is a novel contribution of the present study. As with children, it may be hypothesized that the high protein quality and micronutrient bioavailability associated with animal products may help to maintain women's health.

The interpretation of the adequacy of anthropometric stores among these women is less clear-cut. When compared with WHO references for BMI, these women appear to be largely normal. Yet, when compared with elite women in developing countries [40], these women have a lower mean BMI (22.5 compared with 24.1). In addition, when these findings are compared with those from similar Andean populations, the values for BMI and triceps skinfold thickness fall closer to those published for Peru and Bolivia 15 to 20 years ago (BMI, 22.8 to 23.7; triceps skinfold thickness, 9.8 mm) than to values reported more recently from the Ecuadorian Andes (BMI, 25.6 to 26.1; triceps skinfold thickness, 17.3 mm) [19, 23, 24, 38].

* Leonard WR, Dewalt KM, Stansbury J, McCaston MK. Biocultural determinants of nutritional status and growth failure in rural Ecuador. Paper presented at the symposium: Biocultural models: a coming of age. Atlanta, Ga, USA: American Anthropological Association Meetings, 1994.

In terms of socioeconomic predictors, the principal-components analysis demonstrated that indicators that are often used interchangeably to denote socioeconomic status measured two distinct constructs: modern lifestyle and farming wealth. The distinction between these markers has also been identified by Weismantel [28], Bindon and Vitzthum [29], and DeWalt et al. [41], the latter authors referring to a scale similar to the modern lifestyle as the "material style of life." The important implication for nutritionists is that both of these constructs must be measured and included in models to fully understand the role of socioeconomic status. In addition, the correlations among predictors demonstrated here underline the importance of adjusting the commonly measured variable of women's education for age and socioeconomic markers [29, 42, 43].

The impacts of economic variables have been previously studied mainly in relation to the nutritional status of children. The positive effects of education and literacy on children's diet and growth are frequently reported [39, 44], and education has also been found to covary with adult females' anthropometric status in Kenya and Mexico [35]. In line with our results, Bolivian women's anthropometry was reported to be associated with modern lifestyle but not with traditional farming lifestyle [29]. As noted by Bindon and Vitzthum [29], in addition to being a potential marker of wealth, modern lifestyle may signal less active exercise patterns, a concern given the increasing documentation of obesity among women in Latin America [45].

The age-associated effects merit further consideration. In this population, women in their postreproductive years consumed less food, had lower fat stores, and spent more days ill with respiratory symptoms than younger women. Similar age-related trends have been reported in Papua New Guinea, India, Ethiopia, Zimbabwe, Brazil, and Congo [46–49]. In the Collaborative Research Support Program on Nutrition and Human Function (NCRSP) studies, age was positively associated with BMI in Mexican and Egyptian women but not in Kenyan women [35]. In North America, contrary to the present results, this stage of the life cycle (50 to 65 years) is associated with an increase in fat stores and a decrease in lean body mass and bone density, body composition changes that are associated with such health problems as osteoporosis and sarcopenia. So, although age seems to be linked to body composition, the changes may depend very much on locale and lifestyle, with little information available to guide the interpretation of "adequate stores." Notably, in the present near-census sample of the study communities, no woman was more than 66 years old, suggesting limited survival beyond this stage of life.

The cross-sectional nature of these data leaves the etiology of the lower stores in the Andean postreproductive women unclear. The respiratory symptoms may have resulted in anorexia and thinness, a plausible argument given the existence of tuberculosis in these communities and the practice of cooking over smoky fires. However, energy intake:expenditure imbalance is also a tenable explanation. Energy expenditure may still be high at this age, as these women remain responsible for farm and domestic chores, the cost of which may be compounded by the absence of child labor in postreproductive households.

Conclusions

The present study highlighted variation in access to a high-quality diet by women living in rural communities in the Ecuadorian highlands. Despite consuming a diet largely adequate in energy and protein, the population showed a marked prevalence of inadequate intake of many micronutrients. In line with data demonstrating compromised dietary quality, the economic data showed that Ecuadorian Highland families chose to consume more animal products, as opposed to more energy, as their socioeconomic status increased. This change in dietary quality was in turn positively associated with women's anthropometric measurements in this resource-poor environment.

The observation that older women consumed less food, had lower fat stores, and experienced greater respiratory morbidity, while directly relevant to this specific Andean context, suggests a need for extended cross-cultural studies of the nutritional and health status of postreproductive women. Comparisons among developing countries and with countries in Europe and North America could explore why women in this age group eat less and the factors that appear to put them at risk.

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Children aged 6 to 60 months in Nepal may require a vitamin A supplement regardless of dietary intake from plant and animal food sources

Ruth B. Grubesic

Abstract

The purpose of this survey was to explore the relationship between the prevalence of the health indicators of malnutrition, diarrhea, and acute respiratory infection and the consumption of vitamin A–rich food and the supplementation status of three groups of children in Nepal (supplemented, supplemented only once, and never supplemented). A trained female community health worker interviewed mothers about vitamin A–rich food feeding practices to children aged 6 to 60 months using a standardized questionnaire and then estimated the nutritional status of the children using mid-upper-arm circumference measurements and recording the incidence of diarrhea and acute respiratory infection from mothers' interviews. Regardless of the amount of vitamin A–rich foods consumed, children who were regularly supplemented with high doses of vitamin A were protected against malnutrition, diarrhea, and acute respiratory infection at a higher rate than children who were supplemented only once or were never supplemented. Regularly providing a high-dose (200,000 IU) capsule of vitamin A to children aged 6 to 60 months, including those who eat vitamin A–rich foods, may be effective in decreasing the prevalence of morbidity from malnutrition, diarrhea, and acute respiratory infection.

Key words: Carotenoids, child health, Nepal, retinol, vitamin A plant and animal food sources, vitamin A supplementation

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Introduction

Increasing vitamin A intake among children deficient in that vitamin through diet or supplementation is an important component of comprehensive child-survival programs [1]. Most families in Nepal do not have a vegetable garden, and those who do tend to cultivate vegetables with a low vitamin A content. However, vitamin A–rich foods, such as green leafy vegetables and yellow fruits, are generally available and are found in abundance in most of Nepal.

Animal food sources of vitamin A are available but limited in Nepal because of cultural and financial constraints. Studies have shown that low dietary intakes of vitamin A (both plant and animal) may be related to a variety of reasons: low socioeconomic status, traditional food beliefs and practices, household food-distribution patterns, maternal education, and the fact that young children often are not fed green leafy vegetables [2–4].

The diet in Nepal consists of white rice, a variety of lentils, and a small amount of seasonal vegetables. Most Nepalese eat only two meals a day, but in the morning they will typically have sweet milk tea and fried dough or biscuits. The two "real" meals consist of rice, lentils, and vegetables. In the higher elevations where rice does not grow, potatoes and barley are substituted. Meat is either prohibitively expensive or not eaten for religious reasons. Most Nepalese are therefore restricted to a vegetarian diet for financial reasons.

In Nepal, dark-green leafy vegetables are often considered low-status foods [4]; therefore, even with access to this rich source of β-carotene, mothers may not feed this food to their children. Also, poor hygiene practices in the household, infections, malnutrition, and a low intake of animal food, which is an excellent source of retinol, all contribute to vitamin A deficiency disease [4–6].

Vitamin A occurs as retinol (preformed vitamin A) in animal sources of food [7]. Although food high in retinol may be available, it is expensive and sporadically consumed by vulnerable populations [8]. In some cultures, including that of Nepal, it is not currently feasible to recommend increasing the consumption of animal products because of socioeconomic, religious, and cultural constraints [3, 9].

Provitamin A carotenoids (from plant sources) account for 60% to 70% of vitamin A intake, especially in southeast Asia, Africa, and the western Pacific [2]. Whereas preformed retinol from animal sources (eggs, milk, cheese, liver, and fish oils) is assumed to be 70% to 90% bioavailable when consumed in normal amounts, provitamin A carotenoids are less bioavailable. Only about 16% of the β-carotene contained in the provitamin A carotenoids of food is absorbed and converted to retinol [10]. To obtain 1 μg of retinol equivalent (RE) from food, 6 μg of β-carotene (provitamin A) or 12 μg of other provitamin A carotenoids must be consumed. Some research studies have indicated that the conversion factor is even higher. One study showed that the amount of β-carotene required to obtain 1 μg RE was 26 μg if it was obtained from dark-green leafy vegetables and 12 μg if it was obtained from yellow or orange fruits [11].* A safe daily requirement for vitamin A consumption in children aged 1 to 10 years is 350 to 375 μg RE, with a basal requirement of at least 200 μg RE [10].

This paper addresses vitamin A supplementation and consumption of vitamin A–rich foods (both plant and animal sources) by children 6 to 60 months of age in two districts of Nepal. We examine how the consumption of vitamin A–rich plant and animal foods affected rates of malnutrition, diarrhea, and acute respiratory infection in supplemented, supplemented only once, and never-supplemented children.

Methods

A cross-sectional survey was conducted during June and July 2000 in the mid-hills of Nepal. Children 6 to 60 months of age and their mothers comprised the study group. The study was conducted in Doti and Dhading Districts. Children in Doti received regular vitamin A supplementation. Children in Dhading either received supplementation only once or were never supplemented. Thus, there were three groups of subjects: supplemented (Doti), supplemented once (Dhading), and never supplemented (Dhading).

Within each district, the village leader selected village development committees (VDCs) from areas that were safe enough for fieldwork. (Maoist rebel groups were active in some areas of Nepal at the time.) A VDC is a cluster of up to nine wards composed of a certain number of villages determined by geographic structure and population size. VDC leaders provided lists of villages located within each VDC. The research team visited all listed villages (n = 83) from 43 wards in 8 VDCs selecting a probability sample of households with children aged 6 to 60 months. Households were sampled using a systematic sampling technique by dividing the number of households in the village by 12 and visiting every nth household until 12 children aged 6 to 59 months from each village were sampled. Some villages were too small to allow collection of data on 12 children.

In Doti District, all children in sampled households who had been supplemented with vitamin A capsules during the National Vitamin A Program were included in the study. No cases of never-supplemented children were found in this district.

In Dhading District, all children in sampled households who had not been supplemented were included in the study. Children were excluded if they had been supplemented in the past six months. In this district during polio National Immunization Days (NID) in November 1999, some children received a vitamin A capsule, but it is unclear who decided which children would be the recipients of these capsules. The children who received this vitamin A capsule during the NID were included in the study as a separate group (supplemented only once), since the vitamin A capsule was administered more than six months prior to our fieldwork. Supplementation status within each household was determined by the mother's report (the mother stated if the child received a vitamin A capsule during the NID).

The children came from 304 households in 40 villages in Doti and 283 households from 43 villages in Dhading. More than one child was included per household if the mother had several children between 6 to 60 months of age. However, to allow for some heterogeneity in the sample, only one child from each of three different age groups (6–18, 19–38, and 39–60 months) was included per household. Of the total sample of 876 children, 587 (67%) came from households with one child, 271 (31%) from households with two children, and only 18 (2%) from households with three children.

Socioeconomic status was determined by the father's occupation. These included farmer (on own land or another person's land), India servant/worker (works in India as a taxi driver, house servant, hotel worker, etc.), service occupations (goldsmith, coppersmith, tailor, radio repairman, bank teller, brickmaker, carpenter, construction worker, cycle maker, machine

* As a result of recent research findings, there are currently two units quantifying vitamin A activity in foods, Both refer to 1 μg of all-*trans*-retinol (vitamin A). The retinol equivalent (RE) is defined as equivalent to 6 μg of dietary all-*trans*-β-carotene. The more recently recommended retinol activity equivalent (RAE) is defined as equivalent to 12 μg of dietary all-*trans*-β-carotene. Current food-composition research may still use the 6:1 ratio, because that is what is available in food-composition tables.

shop worker, electrician, furniture maker, hotel cook, mill worker, office worker, peon, river guide, telephone operator, house worker, policeman, army, other military), education and business (accountant, banker, teacher, VDC administrator, medical assistant, hotel manager, laboratory technician, veterinary assistant). Fifty-four percent of children had fathers who were farmers (a low- or no-income occupation), and 2% of fathers were unemployed. The rest of the children came from families with some income, in which the father was a servant or worker in India (16%), was engaged in a service occupation in Nepal (19%), or worked as an educator or in business (9%).

Approval to conduct this study was obtained from the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston and the Nepal Health Research Council under the auspices and coordination of the Institute of Community Health in Kathmandu, Nepal. A female community health worker obtained informed consent and interviewed the mothers, in the Nepali language, regarding the health status of their children, specifically in regard to diarrhea and acute respiratory infection.

She then assessed the mid-upper-arm circumference (MUAC) to determine the child's nutritional status. MUAC measurements were obtained using a mid-upper-arm circumference measuring tape sectioned off in centimeters and color-coded. The MUAC measures arm circumference to the nearest centimeter, with greater than 13.5 cm considered adequately nourished (green), 12.5 to 13.5 cm considered at risk for malnutrition (yellow), and less than 12.5 cm considered malnourished (red). In this study, any child with a MUAC greater than or equal to 13.5 cm was considered adequately nourished, and any measurement less than 13.5 cm was considered malnourished. Sensitivity and specificity curves show that the MUAC is the most sensitive and specific anthropometric measure to assess the risk of a child's dying from malnutrition [12].

The community health worker questioned the mothers using two questionnaires that had been pretested in Nepal. The mother reported whether her child had ever had diarrhea (defined as three or more loose or watery stools per day) or acute respiratory infection (defined as cough with runny nose and/or sore throat). She reported the average frequency of how often the child ate selected vitamin A–rich plant and animal foods during the previous year. These vitamin A–rich food sources were included in the questionnaire because they are foods locally available in Nepal. Food frequency was later recalculated in terms of daily consumption for purposes of analysis.

Quality control measures were taken during the interview process by the primary investigator. Daily data quality (reliability) checks were made to assure that the data were properly obtained and recorded prior to leaving each household. These checks (i.e., repeated measures) helped to determine accuracy in the use of the MUAC measuring tape. The consistency of the mother in answering the survey questions was also determined during this check (test-retest). Interrater reliability was not tested, as the primary investigator was present at each interview, and only one person (the community health worker) conducted all the interviews. The data were double-entered into Epi Info Version 6.04b and edited in Nepal. SPSS Version 10.0 was used for analysis. Epi Info 6.04b was used to obtain prevalence ratios and 95% confidence intervals. An epidemiological approach was utilized. The never-supplemented group in Dhading served as the reference for both the supplemented group in Doti and the supplemented one time only group in Dhading.

Frequency distributions and simple cross-tabulations utilizing chi-square tests ($p < 0.05$) were conducted to evaluate the relationship between consumption of vitamin A–rich foods, supplementation status, and disease outcome. Stratified analyses were conducted to identify covariates with supplementation status as a categorical variable (supplemented, supplemented only once, and never supplemented) and disease outcome (malnutrition, diarrhea, acute respiratory infection) as the binary variable (yes or no).

Results

A total of 876 children (440 supplemented and 436 never supplemented or supplemented only once) between the ages of 6 and 60 months were surveyed during June and July 2000. The data collected were analyzed for three groups according to supplementation status: supplemented (n = 440), supplemented only once 8 months prior to data collection (n = 201), and never supplemented (n = 235). Children were also categorized by age, sex, and father's occupation, serving to indicate socioeconomic status [13]. When the data were stratified for risk factors such as number of children interviewed per household, age, sex, and father's occupation, children who had received vitamin A supplements twice a year since 1993 had better health outcomes, regardless of risk factors [13].

Table 1 shows that the supplemented children consistently had a statistically significant lower prevalence of disease outcomes than the never-supplemented group, and that the prevalence of disease outcome in the group supplemented only once was not significantly different from that in the never-supplemented group of children. Prevalence ratios (PR) were calculated with the never-supplemented group serving as the reference for both exposure groups (supplemented and supplemented only once). There was a protective effect among the vitamin A–supplemented children for all three disease outcomes (malnutrition PR 0.52; 95% confidence interval [CI] 0.39, 0.69; diarrhea PR 0.75; 95% CI 0.67,

TABLE 1. Prevalence of common childhood diseases in children aged 6 to 60 months in Nepal, June and July 2000, according to supplementation status of children

	Supplemented (Doti) (*n* = 440)			Supplemented 1 time only (Dhading) (*n* = 201)			Never supplemented (Dhading)[a] (*n* = 235)	
Disease	%	PR	95% CI	%	PR	95% CI	%	PR
Malnourished	16.6	0.52	0.39–0.69	21.7	0.68	0.49–0.94	32.0	1.00
Protein-energy malnutrition	1.4	0.12	0.05–0.32	15.4	1.65	0.99–2.75	9.4	1.00
Kwashiorkor	0.5	0.05	0.01–0.20	14.4	1.50	0.88–2.52	9.4	1.00
Marasmus	0.2	0.53	0.03–8.50	2.0	4.60	0.53–41.51	0.4	1.00
Diarrhea	57.0	0.75	0.67–0.83	71.6	0.94	0.84–1.05	75.3	1.00
ARI	43.4	0.60	0.53–0.69	74.6	1.03	0.92–1.16	72.3	1.00

PR, Prevalence ratio; CI, confidence interval; ARI, acute respiratory infection.
a. Reference group.

0.83; acute respiratory infection PR 0.60; 95% CI 0.53, 0.69). In the supplemented only once group, there was a significant protective effect for malnutrition (PR 0.68; 95% CI 0.49, 0.94), but not for diarrhea (PR 0.94; 95% CI 0.84, 1.05) or acute respiratory infection (PR 1.03; 95% CI 0.92, 1.16). The small number of cases precluded analysis for protein-energy malnutrition, kwashiorkor, or marasmus (table 1). Diagnosis of these conditions was determined during the interview when the mother was shown a photograph of children with the condition and asked if her child had ever had the condition (yes, no, or don't know).

The mothers reported the frequency of feeding green leafy vegetables, pumpkin, coriander, dried pepper, mango, papaya, milk, ghee (milkfat), meat or fish, and eggs to their children. Data were obtained for average frequency of feeding when the food item was available (many sources are available only seasonally).

According to mothers' reports, only 13.6% of supplemented children in Doti ate more than 3 vitamin A–rich plant sources daily (table 2) and only 10% ate more than 3 vitamin A–rich animal food sources daily (table 3). In Dhading, more children in the supplemented only once group consumed vitamin A–rich foods more than 3 times daily (23.4% for plant sources; 27.9% for animal sources) than children in the never-supplemented group (20.4% for plant sources; 24.3% for animal sources) (tables 2 and 3).

A higher percentage of supplemented children (18.9%) never consumed animal sources of vitamin A compared with supplemented only once (2.5%) and never supplemented children (6%) (table 3). Measurements were not obtained for amount per serving for each source consumed by the child.

Comparisons were made of the daily number of vitamin A–rich foods consumed by children and supplementation status by disease outcome to determine any differences between these groups of children differentiating plant sources (table 2) from animal sources (table 3). Children in the supplemented group, in general, had significantly lower prevalence of all three disease outcomes than children in the unsupplemented group (never supplemented or supplemented once only), regardless of their consumption volume of vitamin A–rich plant or animal foods. Children who never consumed vitamin A–rich food sources had a higher prevalence of malnutrition regardless of their supplementation status; for example, the prevalence of malnutrition among supplemented children who never consumed vitamin A–rich plant sources was 35.6%, compared with a prevalence of 10% for supplemented children who consumed more than 3 plant sources of vitamin A daily. A similar pattern occurs for vitamin A–rich animal sources. This was not the case for diarrhea and acute respiratory infection. The amount of vitamin A–rich plant food consumed did not make a consistent difference in the health outcomes of diarrhea or acute respiratory infection in any of the consumption categories. A child who ate more than 3 vitamin A–rich foods from either plant or animal sources was just as likely to have diarrhea or acute respiratory infection as a child who consumed no vitamin A–rich foods. There were also no significant differences between the supplemented one-time-only and the never-supplemented groups (tables 2 and 3).

Discussion

The Ministry of Health in Nepal initiated a National Vitamin A Program in 1993. This program provides high-dose (200,000 IU as retinyl palmitate) capsule supplementation to reduce child mortality and morbidity related to vitamin A deficiency.

Supplementation is provided twice a year, once in April at the time when food stores are diminished and measles incidence is high, and again in October prior to the rice harvest. The dates are fixed, which facilitates yearly planning. Female community health volunteers distribute the capsules in their individual communities to all children under the age of five years during the two-day supplementation campaign. Capsule cover-

TABLE 2. Prevalence ratios for plant sources[a] of vitamin A and supplementation status of children aged 6 to 60 months in Nepal, June and July 2000, according to disease outcome

Daily intake[b]	%[c]	Supplementation status	MUAC[d]			Diarrhea			ARI		
			%	PR[e]	95% CI	%	PR	95% CI	%	PR	95% CI
0	13.6	Supplemented ($n = 60$)	35.6	0.91	0.58–1.42	46.7	0.65	0.48–0.88	45.0	0.57	0.42–0.78
	15.4	Supplemented 1 time only ($n = 31$)	46.7	1.19	0.74–1.92	83.9	1.17	0.95–1.45	83.9	1.07	0.88–1.30
	31.5	Never supplemented ($n = 74$)	39.2	1.00		71.6	1.00		78.4	1.00	
1	30.7	Supplemented ($n = 135$)	12.7	0.40	0.23–0.69	50.4	0.67	0.54–0.83	43.0	0.69	0.53–0.90
	31.8	Supplemented 1 time only ($n = 64$)	19.0	0.60	0.32–1.09	68.8	0.92	0.74–1.13	75.0	1.21	0.97–1.52
	32.3	Never supplemented ($n = 76$)	32.0	1.00		75.0	1.00		61.8	1.00	
2–3	42	Supplemented ($n = 185$)	15.4	0.41	0.24–0.72	63.8	0.76	0.64–0.91	45.9	0.63	0.49–0.81
	29.4	Supplemented 1 time only ($n = 59$)	13.8	0.37	0.17–0.81	67.8	0.81	0.65–1.01	72.9	1.00	0.78–1.28
	15.7	Never supplemented ($n = 37$)	37.1	1.00		83.8	1.00		73.0	1.00	
> 3	13.6	Supplemented ($n = 60$)	10.0	0.59	0.22–1.58	61.7	0.82	0.64–1.06	35.0	0.44	0.30–0.64
	23.4	Supplemented 1 time only ($n = 47$)	19.1	1.13	0.47–2.66	72.3	0.96	0.76–1.23	70.2	0.89	0.70–1.12
	20.4	Never supplemented ($n = 48$)	17.0	1.00		75.0	1.00		79.2	1.00	

MUAC, Mid-upper-arm circumference; ARI, acute respiratory infection; PR, Prevalence ratio; CI, confidence interval.

a. Plant sources include green leafy vegetables, pumpkin, coriander, dried pepper, mango, and papaya.

b. 0 = do not eat plant sources of vitamin A; 1 = eat one or fewer plant sources of vitamin A at least once daily; 2 = eat 2 to 3 plant sources of vitamin A at least once daily; 3 = eat plant sources of vitamin A more than 3 times daily.

c. Percentage of children consuming plant sources of vitamin A–rich foods daily, by supplementation status.

d. MUAC < 13.5 cm considered malnourished.

e. The never-supplemented group serves as the reference for both exposure groups. The upper prevalence ratio is supplemented vs. never supplemented; the lower prevalence ratio is supplemented one time only vs. never supplemented.

age (based on mini surveys of capsule distribution) is estimated to be between 86% and 90% [14].

This survey found that children who have been supplemented with vitamin A capsules regularly twice a year in the Nepal National Vitamin A Program in Doti District had better health outcomes for malnutrition, diarrhea, and acute respiratory infection than those children either supplemented only once or never supplemented in Dhading District.

Children in the supplemented group had a lower prevalence of disease, yet consumed fewer vitamin A–rich food sources than children in the supplemented only once and never-supplemented groups. Children in the these groups had a higher prevalence of all three disease outcomes, yet they ate more vitamin A–rich foods. Consumption of vitamin A–rich foods alone did not protect them from having malnutrition, diarrhea, or acute respiratory infection. However, the never-supplemented children with the highest consumption of vitamin A–rich plant foods had the lowest prevalence of malnutrition, and the never-supplemented children with the highest consumption of vitamin A–rich animal foods had lower prevalences of all three disease outcomes than children consuming no vitamin A–rich foods, whether supplemented or not. Based on our observations, it appears that vitamin A–rich plant and animal foods may protect children from adverse disease outcomes, but not as much as regularly scheduled supplementation.

Research studies have shown that children deficient in vitamin A are more susceptible to infections and certain diseases, such as malnutrition, diarrhea, and acute respiratory infection [10, 15, 16]. Children who receive a high-dose (200,000 IU) vitamin A capsule one time only are provided with protective health effects for approximately four to six months [17]. In

TABLE 3. Prevalence ratios for animal sources[a] of vitamin A and supplementation status of children aged 6 to 60 months in Nepal, June and July 2000, according to disease outcome

Daily intake[b]	%[c]	Supplementation status	MUAC[d]			Diarrhea			ARI		
			%	PR[e]	95% CI	%	PR	95% CI	%	PR	95% CI
0	18.9	Supplemented (*n* = 83)	20.7	0.30	0.17–0.52	60.2	0.70	0.53–0.93	41.0	0.41	0.32–0.53
	2.5	Supplemented 1 time only (*n* = 5)	50.0	0.72	0.25–2.05	40.0	0.47	0.16–1.39	40.0	0.40	0.14–1.17
	6	Never supplemented (*n* = 14)	69.2	1.00		85.7	1.00		100.0	1.00	
1	23.6	Supplemented (*n* = 104)	10.7	0.32	0.17–0.61	54.8	0.67	0.55–0.82	39.4	0.52	0.39–0.67
	27.9	Supplemented 1 time only (*n* = 56)	27.8	0.83	0.49–1.42	76.8	0.94	0.79–1.13	69.6	0.91	0.74–1.12
	34.5	Never supplemented (*n* = 81)	33.3	1.00		81.5	1.00		76.5	1.00	
2–3	47.5	Supplemented (*n* = 209)	19.9	0.79	0.50–1.25	57.9	0.81	0.68–0.97	44.0	0.62	0.50–0.76
	41.8	Supplemented 1 time only(*n* = 84)	20.2	0.80	0.46–1.40	71.4	1.00	0.83–1.22	81.0	1.14	0.96–1.35
	35.3	Never supplemented (*n* = 83)	25.3	1.00		71.1	1.00		71.1	1.00	
> 3	10	Supplemented (*n* = 44)	6.8	0.22	0.07–0.69	52.3	0.74	0.54–1.04	54.5	0.89	0.63–1.25
	27.9	Supplemented 1 time only (*n* = 56)	16.1	0.51	0.25–1.04	69.6	0.99	0.78–1.26	73.2	1.19	0.92–1.55
	24.3	Never supplemented (*n* = 57)	31.6	1.00		70.2	1.00		61.4	1.00	

MUAC, Mid-upper-arm circumference; ARI, acute respiratory infection; PR, Prevalence ratio; CI, confidence interval.
a. Animal sources include milk, ghee, meat, fish, and eggs.
b. 0 = do not eat animal sources of vitamin A; 1 = eat one or fewer animal sources of vitamin A at least once daily; 2 = eat 2 to 3 animal sources of vitamin A at least once daily; 3 = eat animal sources of vitamin A more than 3 times daily.
c. Percentage of children consuming animal sources of vitamin A–rich foods daily, by supplementation status.
d. MUAC < 13.5 cm considered malnourished.
e. The never-supplemented group serves as the reference for both exposure groups. The upper prevalence ratio is supplemented vs. never supplemented; the lower prevalence ratio is supplemented one time only vs. never supplemented.

the Nepal Micronutrient Status Survey [18], children were found to have an equal chance of having subclinical vitamin A deficiency if they were unsupplemented but had adequate dietary intakes of vitamin A or if they were supplemented but lacked adequate dietary intakes of vitamin A–rich foods.

This paper has shown that children from a district with low coverage of vitamin A supplementation with many vegetables available still do not consume enough vitamin A–rich foods to sufficiently protect them from selected disease outcomes. Even those children who received a vitamin A capsule one time only were not as protected as children who received vitamin A on a regular twice-yearly schedule. It does appear that the combination of supplementation with consumption of vitamin A–rich plant foods may provide better protection from malnutrition, and that supplementation with consumption of vitamin A–rich animal food sources may provide better protection from diarrhea. Preschool-age children in Nepal still require supplementation on a scheduled twice-yearly regimen, regardless of dietary intake.

Study limitations

This is a descriptive, cross-sectional survey conducted in two mid-hill districts of Nepal. Every effort was made by the researchers to make the samples as homogeneous as possible between the two districts while allowing for heterogeneity within the villages with respect to the demographics of the children. The findings presented in this study are meant to show associations only, not a cause-and-effect relationship of supplements or diet to disease outcome. Much of the data collected for this survey depended on mothers' recall during interviews. Mothers were asked to recall how often their children were sick with diarrhea, how often they fed them vitamin A–rich foods, and whether their children received vitamin A during NID in November 1999. Data on the mothers' literacy and educational level were not obtained. According to UNICEF, the adult literacy rate for females is 35% [19]. Literacy levels may help explain why some mothers breastfed longer or fed their children more healthful foods. Data were not obtained on portion size of the foods eaten, only the frequency of vitamin A–rich food sources consumed by the child. There is a possibility of selection bias because children who received vitamin A capsules during NID may have other factors that protect them from disease, for example, it may be that a mother with higher education and literacy levels may be more likely to understand the importance of giving her child a vitamin A capsule during NID. Social status determined by caste in Nepal may also play a role.

Conclusions

These results support continued efforts by the National Vitamin A Program in Nepal to supplement children twice a year with vitamin A capsules. The cost of supplementation is minimal compared with the positive health outcome of providing capsule supplementation. Infant and child deaths could be reduced globally by vitamin A supplementation at a distribution cost of less than US$1 per year per child [20]. Vitamin A capsules cost only US$0.02 per capsule [10] (dosed two times per year), and supplementation can result in a 23% decrease in mortality for children between 6 months and 5 years of age [21]. As long as there is funding and there are trained Nepali female community health volunteers who are able to take on the task of distributing the capsules, children should continue to receive vitamin A supplementation twice yearly.

To improve vitamin A status in children, it has been suggested that programs emphasize increasing the production and consumption of locally available carotenoid-rich foods [16], and that promoting dietary change be recommended for combating vitamin A deficiency in young children [3, 10]. Research studies have shown that access to home gardening and animals does not always ensure that the diet is sufficient to prevent vitamin A deficiency [4, 22]. An intervention conducted on kindergarten children in China [23] suggested that for effective long-term improvement of vitamin A status, interventions should be food based and started early in life. Vitamin A status did improve in children in the Chinese study who were fed vitamin A–rich foods in school when the type and amount of food consumed was closely monitored. In Bangladesh, mothers who were provided education on the appropriate preparation of vegetables were more likely to feed their children vegetables two months post-intervention [10]. These approaches may not be practical in field conditions with large populations at risk.

Supplementation with vitamin A capsules reduces morbidity from malnutrition, diarrhea, and acute respiratory infection. It also reduces mortality associated with certain diseases [10]. By the end of the year 2001, the National Vitamin A Program should have supplemented all of the children in Nepal at least once. The health of Nepal's children depends in part on the efforts of this program. If sustainability of the National Vitamin A Program in Nepal is not feasible for financial or other reasons, the necessity of food-based interventions will be inevitable. Most children in Nepal do not receive vitamin A in sufficient quantities from their diet, for both cultural and financial reasons. More research is needed on dietary approaches that are effective to combat vitamin A deficiency in Nepal. Determining how to implement a food-based intervention that will provide adequate amounts of vitamin A in the case that supplementation is no longer feasible is of utmost importance at this time. Efforts made now will assure a smooth transition from supplementation to food-based interventions or provide a complement to supplementation if it is sustained. Over the last few years, there has been an emphasis on improving the diet of populations at risk [24]. Ultimately, this will help provide governments in countries like Nepal with an opportunity to shift away from supplementation and develop a more sustainable approach to improving vitamin A status in vulnerable populations.

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