Functional Implications of MALNUTRITION

KENYA PROJECT

Final Report

Human Nutrition
Collaborative Research
Support Program

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DIET QUANTITY AND QUALITY

Functional Effects on Rural Kenyan Families

KENYA PROJECT FINAL REPORT
PHASE II - 1989-1992

HUMAN NUTRITION
COLLABORATIVE PROGRAM
SUPPORT PROGRAM*

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BRIEF SUMMARY OF KEY FINDINGS

1. Mild-moderate malnutrition, far more prevalent than severe malnutrition, is associated with chronically low food intake and a high infectious disease burden.

2. Human function, particularly growth, reproductive outcome, cognitive development, disease resistance and activity are adversely affected by mild-moderate malnutrition.

3. Diet quantity (energy) and diet quality (micronutrients) are both necessary for optimal function. Both aspects of the diet are deficient in the study population. Poverty, unreliable rains, limited agricultural inputs and large family size limit the quantity of intake. Dependence on a maize diet with high fiber and phytate content and extremely low intake of animal source foods and fat, and low socioeconomic status limit diet quality. Lack of universal iodized salt use in this iodine deficient area also contributes to poor diet quality.

Reproduction

4. The woman's size upon entry into pregnancy and food intake during pregnancy determine her gestational weight and fat gain, the size of the infant at birth and also the infant's growth from 0 to 6 months of age.

   Women were observed to lower their energy intakes by 25 to 30 percent of their pre-pregnancy intake and to gain 50 percent of the recommended gestational weight gain. Fetal growth occurs at the expense of body fat, muscle and weight and the women enter lactation with reduced fat stores to support lactation.

5. Women with mild-moderate malnutrition with diets deficient in energy and micronutrients give birth to infants with mean birth weights close to reference values. However, the mean birth length is below normal (20th percentile) and 16 percent of infants are considered small for their gestational age, indicative of maternal malnutrition.

6. Mothers with meager fat stores in pregnancy and lactation and who do not increase their lactational intake do not support optimal growth in their infants. The question of lactation adequacy, i.e., milk volume and composition, is raised.

Stunting

7. Poor linear growth starts in utero and further declines between 3 to 6 months of age to a level considered to be stunted (-2 z-scores).

8. Once stunted, toddlers, schoolers and adolescents grow at a low normal incremental rate and are short as adults. Energy, zinc, iodine and calcium intakes which are

associated with growth retardation, remain low in the diet and no appreciable catch-up growth is observed except for a small amount in menarcheal girls.

9. The main determinants of poor growth are limited diet quantity and quality, parental size (particularly maternal), illness prevalence and low socioeconomic status.

10. Adverse effects of stunting are observed in reproduction, cognitive function and illness resistance.

Morbidity

11. Low levels of food intake, particularly animal protein and fat, and short stature predict severe illness in children and adults. Mild illness is more closely related to household sanitation, parental literacy and household illness exposure than to food intake. However, a mother's food intake is a deterrent to mild illness in her children because of her ability to better care for them and for the household.

12. In toddlers, energy intake was found to decrease significantly during common febrile illnesses. Despite compensatory eating in convalescence, particularly with severe illness, the deficit is not made up over time. Given the high illness prevalence and long duration of severe illness, the decreased intake and growth deficit can be considerable.

Adaptations to low energy intake

13. Increased work efficiency or lowering of resting energy expenditure (REE) were not found in relation to changes in food intake. REE measured in men and pregnant women before, during and after a severe food shortage demonstrated that there are no "cost-free" adaptations to reduction in energy intake. The "adaptations" are decreased activity (observed in women) and weight loss, both detrimental to health and productive activities.

Lessons learned from a severe drought-associated food shortage

14. Food supply is extremely fragile in rain-dependent subsistence agriculture communities. Food security issues are covered above.

    Indicators (determined retrospectively) found to be useful for an early warning system for impending food crisis are:

    Acute weight loss in adults and schoolers.
    Missed anticipated rains.
    Appearance of unusual and uncommon foodstuffs in the family diet.
    Flooding of markets with inexpensive animals (goats) for sale and for slaughter.
    Steep rise in prices for scarce staples brought in from other areas.
    Interviews with farmers who can foretell failed harvest from crop behavior.
    Sale of household goods and amenities in the market to raise cash.

The above list of findings were those of most interest to Kenyan policy makers and agencies. Policy and programmatic implications are discussed in the last chapter.

CHAPTER ONE.
INTRODUCTION AND BACKGROUND

This report is a culmination of 10 years of planning and preparation, field research, data analysis and writing. The report covers analytic activities of Phase II, since 1989. However, the report does incorporate and integrate earlier work where newer analyses build on the initial analyses. This first chapter provides a brief amount of background information useful for understanding the project's development and design, and how this report is organized. A more complete discussion of the background and overall study methodology can be found in the 1987 Final Report of the Nutrition CRSP Kenya Project.

PROJECT BACKGROUND AND OBJECTIVES

Although it is well documented that severe malnutrition, results in the impairment of human function, the impact of chronic mild-to-moderate malnutrition on human function has been less clear. This issue has tremendous potential importance for billions of people throughout the developing world and the poor populations in the industrialized world who are affected by chronic mild-to-moderate malnutrition. In 1977, the National Academy of Sciences (N.A.S.) undertook a review of the status of world food and nutrition. The resulting study identified chronic mild-to-moderate malnutrition as the highest priority area for research on world food and nutrition issues. In 1978, the United States Agency for International Development (USAID) developed the Nutrition Collaborative Research Support Program (CRSP) and awarded this grant to the University of California, Berkeley and its subgrantees. It was funded by USAID as of 1981. The program took the form of a multidisciplinary three country study focusing on five interrelated areas of human function related to food consumption: disease response, reproductive competence, growth, cognition, and socio-behavioral performance and physical activity. Resting energy expenditure studies were included to test for metabolic adaptation to changes in food intake.

Similar research protocols were utilized in study communities in three countries Kenya, Mexico, and Egypt characterized by chronic mild-to-moderate malnutrition. This was done so that the research findings could be compared across countries that differ in their staple foods, agricultural systems, physical environments, and cultures, and hence would strengthen any common relationships found between energy intake and function. Also, the findings would be made generalizable to other populations. Such comparisons were facilitated by standardizing not only the research hypotheses, but also the protocols and methodologies as much as was realistic across geographic and ethnic boundaries. The Nutrition CRSP focused not only on specific individuals but on the household as the unit of analysis. Food intake was the main independent variable.

The hypotheses that directed the Nutrition CRSP research were:

1. Maternal food intake during pregnancy and lactation influences infants' endowment at birth and growth and development during the first six months of breast feeding. Thus, infant body size, psychological development, and morbidity are affected by maternal food intake.

2. Food intake of toddlers during the period from 18 months through 30 months affects their morbidity, growth and psychological development.

3. Food intake of 7-9 year-old children affects their morbidity, growth, cognitive function, school performance, behavior and activity level.

4. Food intake of adults influences their level of health, their care of and attention to their children, their social-emotional responsiveness, and their performance of usual tasks. These functional outcomes impact upon other members of the household, i.e., as in the case of children's cognitive performance.

5. In adults and schoolers, a reduction of resting metabolic rates provides a major path of adaptation to restore energy equilibrium in the face of decreased energy intake.

6. Household food intake affects household morbidity.

DATA COLLECTION

Following a pilot study in 1983, the bulk of the data collection took place between January 1984 and March 1986, although several follow-up studies of former CRSP subjects have taken place as recently as 1991.

THE STUDY POPULATION

In order to explore the above hypotheses, participant households were chosen based on the presence of appropriate target individuals: a woman likely to become pregnant or in the first trimester of pregnancy, her husband who resides at home and works in the area; a 15-18 month-old toddler, or a school-age child between seven and eight years. The goal was to collect twelve months of data on each target child and his or her biological parents residing in the household. The mother-child pair was studied at least six of the nine months of pregnancy and the first six months of the infant's life. The toddlers were studied from 18 to 30 months of age, and the schoolers from 7 to 9 years or a minimum of one year. Limited data were also collected on non-target individuals residing in the household.

CRITERIA FOR COMMUNITY SELECTION

Criteria for community selection were as follows: population stability, with minimal in and out migration; population homogeneity; sufficiently large community to supply an adequate sampling frame; range of nutritional status, but mainly mild-moderate malnutrition and not a preponderance of severe malnutrition; representation of target individuals within the population; infrastructure and cooperation of community leaders; accessible to location of collaborative host institution and co-investigators (within 200 miles).

SAMPLING

The Nutrition CRSP Kenya Project selected a convenience sample of 290 Embu households selected from a total of 2059 households surveyed in the sublocational area scattered over a 60 square kilometer area. The initial location of households was done by aerial survey and mapping because of the scattered nature of the households.

Criteria for enrollment was based on acquiring an adequate number of family member types for the whole study, including infants, toddlers or school-aged children to assure proper statistical significance during analysis. Of the 290 households enrolled, 247 households (87%) completed participation in the study. The sample matched the characteristics of the general area. The sample of households selected differed little from the preliminary survey findings of the 2000 households. The group of dropouts differed from the main study sample only in that a number of households had males and females who had salaried employment and could not be home, or families moved away.

DESIGN

The design was quasi-experimental and longitudinal with several cross-sectional studies. Pilot studies showed a range of values for the independent variable and criteria measures. It was naturalistic, observational and non-interventionist in nature.

DATA COLLECTED

Key functional outcomes were growth and changes in body composition; morbidity and reproductive outcome including infant growth during lactation; cognitive and behavioral performance. Data was also obtained on explanatory measures such as resting energy expenditure and activity; a number of intervening or confounding variables and important community level measures ie: rainfall, temperature, market prices, etc. Food intake collected 2 days per month for a minimum of one year was considered valid representation of usual individual and household intake. Anthropometry was not a surrogate for food intake, but used as an intermediate expression of food intake.

Six major "core" research topics were investigated by the Kenya Project. The major areas for which data was collected were:

Core Data Collected

FOOD INTAKE
Meal Preparation
Target individual/guest kcal consumed
Non target individual (non meal foods and food taken outside the H)
Meal preparation - summary
Consumer unit
Target individual/nontarget individual - summary
kcal intake summary

ANTHROPOMETRY

Anthropometry: stature, weight, arm circumference, fat folds

MORBIDITY

Disability and chronic disease quarterly update
Individual four weekly report
Household four weekly report-target and non-target individuals
Clinical examination summary

IMMUNOLOGY AND HEMATOLOGY

Laboratory - hematology, immunology, stool examinations

REPRODUCTION AND LACTATION

Reproductive history
Pregnancy survey
Pregnancy outcome
Lactation questionnaire
Dubowitz scale for gestational age

COGNITION

Infant behavioral and neurological assessment scale (Brazelton)
Infant-Bayley
Infant, toddler - caretaker interaction
Resting energy expenditure
Household measures
Toddler - Bayley
Schooler - Ravens, WISC items
Schooler classroom observations
Schooler playground observations
School attendance
Cognitive adult - Ravens, WAIS items
Care-giving activities
Adult literacy

RESTING ENERGY EXPENDITURE

Resting metabolic rate

HOUSEHOLD MEASURES

Socioeconomic status (SES)
Household economic questionnaire
Sanitation and hygiene (SAHY)
Sanitation and hygiene observations
Census update

Non-Core Data Collected

TIME ALLOCATIONS

Time allocation - all household members

AGRICULTURE PRODUCTION

Agriculture, crop, questionnaire
Seed planting questionnaire
Market survey - summary

ENERGY EXPENDITURE OF ACTIVITY

Energy Expenditure

ADULT LITERACY

Adult literacy test

ANXIETY AND DEPRESSION

Anxiety and depression self report questionnaire (951 part 1)

ALCOHOL CONSUMPTION

Alcohol consumption questionnaire

DROUGHT EXPERIENCES AND RESPONSES

Drought questionnaire

OTHER SUPPLEMENTARY FORMS

Entry/change/exit
Census update
Weather data - rainfall, temperature, humidity

THE STUDY SITE

Embu, Kenya, is a district containing about 180,000 Bantu-speaking persons (with over 26,000 in the study area) located about 120 miles northeast of Nairobi on the slopes of Mount Kenya (see Figure 1.1). The community lies at an altitude of approximately 3,000-4,500 feet, and its climate is fairly mild and dry for most of the year, with short and long rainy seasons. Health facilities are present, but the people lack electricity and convenient access to safe water and transportation. Although schooling is available, much of the population has only limited reading ability.

The study area is populated by small landholder agriculturalists producing both subsistence and cash crops. The principal subsistence food crops are white maize and kidney beans. Many also grow English potatoes, sweet potatoes, cowpeas, bananas, cassava, millet, sorghum, and arrowroot as secondary crops. The main cash crops are coffee and cotton. A few households cultivate small amounts of tobacco.

Many households also keep small numbers of cattle, goats, and chickens and engage in temporary or permanent remunerative labor. Most cash labor (aside from that for household cash crops) is in either the agricultural fields of larger landowners, local small industries (such as carpentry, blacksmithing, tailoring), or the rural service sector of shops, hotels and restaurants. Other cash-earning opportunities are the production and sale of commodities such as charcoal, milk, wood, and honey.

General State of Health

The infant mortality rate for Eastern Province is 77/1000 live births, of which 52% are neonatal deaths. The leading causes of death among infants are pneumonia, tetanus, diarrhea, measles, and malnutrition (1). The percentage of stunted children under 5 years of age in Embu is 22%, while the average for Eastern Province is 27% (1). Life expectancy for adults is 53 years at birth (2), and maternal mortality is approximately 32.9 per 10,000 (3).

REPORT ORGANIZATION

The above background information is intended to introduce the contextual setting for the bulk of this report. The following chapters review the specific findings of the analyses related to the hypotheses. A number of these chapters are compilations of published papers and those in the process of publication. Others represent new analyses which have not yet been presented independently. For further details we suggest consulting the papers referenced at the end of each chapter.

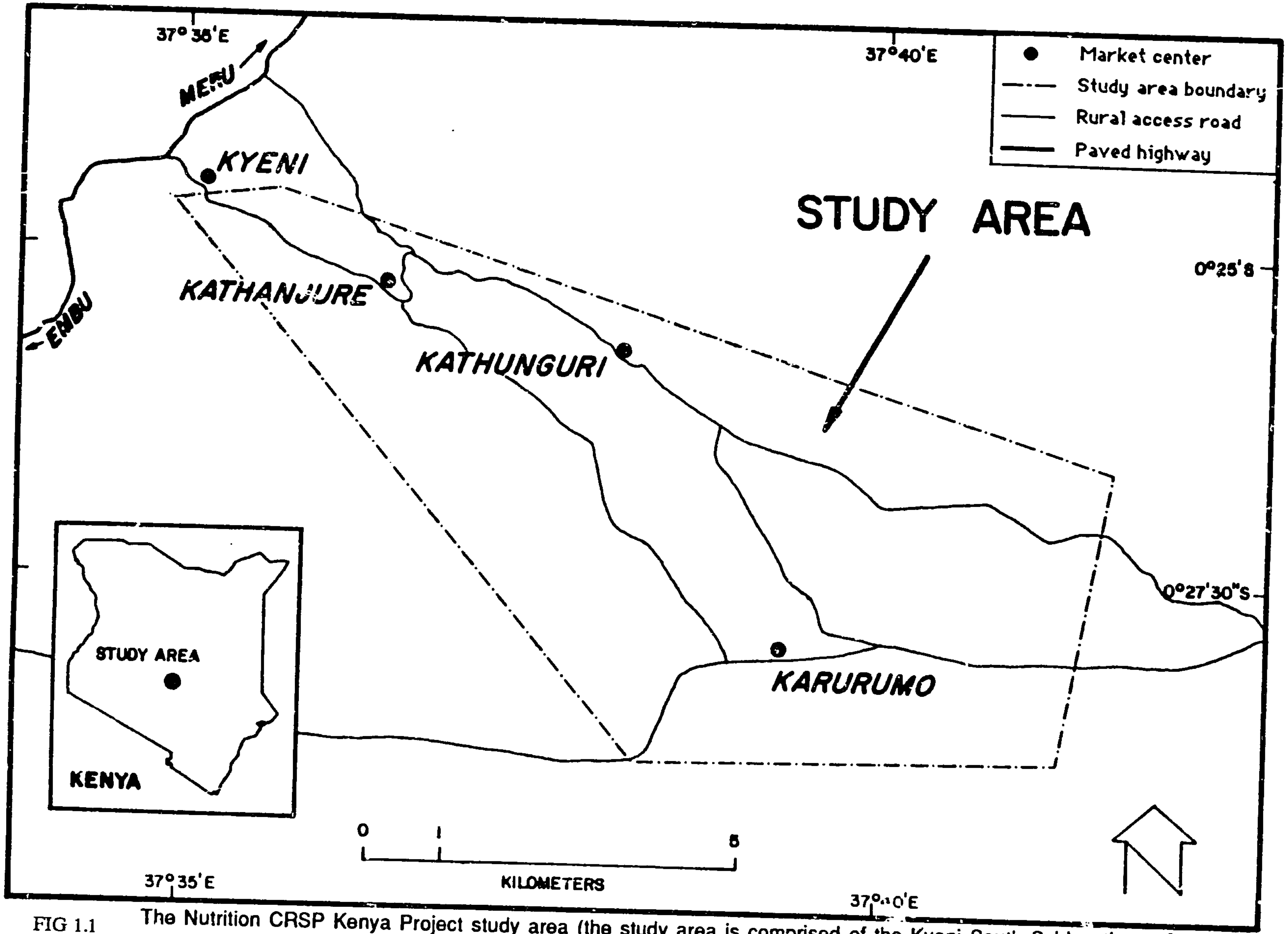

FIG 1.1 The Nutrition CRSP Kenya Project study area (the study area is comprised of the Kyeni South Sublocations of Kathanjure, Kathunguri, and Karurumo; the Kenyi South Sublocations of Kigumo and Kasafari lie to the north and east of the study area, respectively).

The body of the report is organized as follows. Chapters Two through Nine summarize the findings of the major study areas. Chapter Two presents the results of the quantitative and qualitative analysis of food intake. Chapter Three is a descriptive presentation of morbidity among the study population, its determinants and impact on function. Chapter Four reviews reproductive outcomes as a function of nutrition prior to and during pregnancy and lactation. As a logical next step, growth and stunting from infancy through adulthood are examined in Chapter Five. Cognitive and behavioral outcomes of nutrition and home environment are discussed in Chapter Six. Chapter Seven examines the effect of both chronic and acute low energy intake on resting energy expenditure in adult men and pregnant and non pregnant women to look for metabolic adaptation in response to decreased energy intake or increased energy needs. Chapter Eight summarizes the findings of the time allocation studies, providing insight into the usefulness of such studies as they relate to food procurement and energy expenditure. The widespread effects of the drought that occurred in the study area in 1984 are the subject of Chapter Nine.

Chapter ten brings together the major findings and their policy implications including possible interventions. A summary of project activities and a bibliography of published papers, presentations, abstracts and other reports which have resulted from the Kenya Nutrition CRSP can be found in the appendices.

REFERENCES

1. Republic of Kenya. Situation analysis of children and women in Kenya, Section 4, The Wellbeing of Children. Nairobi, Kenya: Central Bureau of Statistics, Ministry of Finance and Planning, 1984.

2. UNICEF. The State of the World's Children. Oxford: Oxford Press, 1986.

3. World Health Organization. World Health Statistics. Geneva: WHO, 1982.

CHAPTER TWO.
FOOD INTAKE

INTRODUCTION

As background to understanding the diet and food supply in Embu District, some salient features of the study area are presented. The area is located on the southeast slopes of Mt. Kenya. The 60 sq km study site ranges in altitude from approximately 920 meters (3,000 ft) to 1,540 meters (5,000 ft) above sea level. The closest municipality to the study site is the town of Runyenjes, with a population of about 2,000, which has markets for the sale and purchase of selected food items and other household and farm necessities. There are other smaller food markets spread throughout the study area, selling mainly produce, beans and grains.

Rainfall varies considerably throughout the district. Altitude and exposure to wind are the principal determinants of rainfall levels and agricultural zonation. Rainfall is the most significant climatic factor, as it is the major consideration with regard to land use and thus the level of economic and agricultural development. Rainfall is concentrated into two distinct seasons, the long rains and the short rains, which dictate the structure of growing seasons and of food production. The area is subject to periodic droughts with severe food shortages about every 10 to 12 years (See Chapter Nine for a discussion of the 1984 drought) (1).

Embu agriculture is entirely rain-fed and it is a struggle to produce enough food for family consumption and secondarily to provide a source of cash income. The average farm size is 1.86 ± 1.51 ($\bar{x}$±SD) hectares (ha); farms range from .05 to 6.20 ha. Most farmers produce a combination of food and cash crops. The primary food crops are maize and beans and the major cash crops are coffee, cotton, and tobacco. Maize occupies approximately 24% of cultivated land, beans 25%, and coffee 12.5%. The average yearly household yield of maize in 1985 to 1986 was 720 kg ± 629 ($\bar{x}$±SD), and the bean yield was 606 kg ± 639. Theoretically, this could supply a household with an average size of seven people with about 1900 kcal per person per day for one year. However, part of the yield is saved for seed or sold for cash. A small portion is stored for future use, but storage losses also reduce the available household food supply (2).

Harvested crops perceived to be in excess of consumption needs are sold through local markets or the National Cereals and Produce Board. The income is used to purchase food items not provided by the farm or to pay other expenses such as school fees and the cost of agricultural inputs. Ironically then, at times of shortage (typically in pre-harvest periods), the farmer must buy back maize and beans at higher prices than their selling prices (2).

Since the mid-1970's, food crop production per capita in Kenya has been on the decline and agriculture has been expanding into the country's drier zones, increasing the threat from drought. Indeed, drought has been a major contributor to the reduction in food production. The pressure for available cash results in households using food crops as cash crops and storing little or none for times of shortage.

Studies as early as 1925 noted inadequacies within the Kenyan diet (3). The Food and Agriculture Organization (FAO) conducted a detailed food consumption survey in 1964-66 and concluded that there were serious problems due to poor regional and household distribution (4).

As described in earlier reports, the general nutritional status of the area can best be described as mild to moderate protein-energy malnutrition with a high percentage of stunted individuals. Data collected during the Nutrition CRSP study provide a detailed picture of the nutritional status of the people within the area (see Chapter Five). Briefly, the men are thin for their age and have low body mass index ($BMI=wt/ht^2$) and body fat, and 23% of lead females were reported as underweight with 6% being classified as wasted. Children are much the same as adults. Between 27 and 48 percent (depending on the season) of all school-age children are considered moderately malnourished, with only 1.5% identified as severely malnourished. Toddlers, age 18-30 months, demonstrate very little severe malnutrition, but 27% are stunted and 30% are moderately underweight (71 to 80 percent of median weight for age).

Two main aspects of food intake examined in detail are quantitative and qualitative aspects of the diet in the Kenya Nutrition CRSP sample. Of particular concern are quantity of energy intake and intake of animal source foods, focusing on zinc and iron and their bioavailability, and on vitamin B_{12}. Intakes of the B-vitamins, particularly B_{12}; riboflavin; vitamin A; iodine; and calcium, are also very low. Iodine deficiency, based on clinical and biochemical evidence and water analyses is also present in the area. Identification of specific food items and diet patterns which contribute the main nutrients is of great importance as a basis for future nutrition education and intervention.

METHODS

A quantitative method for obtaining food intake information and quality control procedures were fully described in the 1987 Kenya Nutrition CRSP Final Report and in a publication by Murphy, et al (5).

Food Intake Method

In brief, the Nutrition CRSP Kenya Project developed a quantitative method to collect data on food prepared and consumed by study household members. The method included direct weighing and volume measurements of ingredients and cooked dishes, and also recall of consumed foods and prepared dishes when direct measurement was not possible. "Child following" was utilized for the toddlers whenever possible to observe and record self-obtained snacks. Limited following of schoolers also took place.

Food preparation/consumption information was recorded for two consecutive days per month in each of the 247 study households for a period of one to two years. The fieldworkers (women) were in the household from 7:00 a.m. to 6:00 p.m. The data collection schedule was staggered throughout the week in order to collect food intake information that represented all days of the week, but took place on only one Sunday per month, at the respondents' request. Recall data on foods prepared and consumed following the enumerator's departure on the evening of the second day were recorded on the third morning. Data were collected on all target and non-target individuals, as well as on guests who consumed food prepared by the household. All meal foods, non-meal foods (snacks), foods consumed away from home, and foods received elsewhere and brought home, were included. This method generated over 20,000 days of dietary data and over 100,000 food items consumed.

Development of a nutrient data base for Kenyan food items

Food composition tables, based on biochemical analyses of the main local foods and values from relevant food tables, were constructed to determine nutrient composition of the foods consumed.

Production of a nutrient data base was carried out as a cooperative effort between the Kenya Project staff and the Nutritional Sciences Department at the University of California, Berkeley.[1] Because there were no food composition tables available for Kenyan foods, development of a food-to-nutrient conversion system for the Nutrition CRSP Kenya Project was developed. The actual computer conversion was performed at Berkeley using field data, and the results were then sent to UCLA and Kenya for use in data analyses.

The multi-step process consisted of development of a nutrient data base, calculation of the nutrient values of individual household recipes, development of nutrient values for standard recipes and calculation of nutrient totals for individuals and households. Quality control checks were performed at each step. The development of the nutrient data base is fully described in a publication by Murphy et al (5). Salient points will be described here.

A list of foods and dishes consumed by the survey population was developed by the senior field nutritionist, and her staff assigned codes to these items. Approximately one-third of the codes refer to food items and the remainder refer to mixed dishes (recipes). The nutrient data base originally contained five nutrients for each food item: energy, protein, fat, carbohydrate and iron. Nutrient values are per 100 grams of the food item. Sources of nutrient values included: laboratory analyses of food items, USDA Handbook 8 (6), FAO values for foods in Africa (7), Platt (8), and McCance and Widdowson (9). When a

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[1] The University of California group included D. Calloway, S. Murphy, D. Lien, G. Beaton (consultant), and M. Hudus. The UCLA group consisted of A. Coulson, W. Choi, S.W. Andersson, field nutritionist, and B. Browdy.

published value could not be found, a value was assigned from a similar food. The final food item nutrient data base contains 180 food items, including eight hotel foods (foods commercially prepared in small restaurants).

Calculation of Nutrient Values for Household Recipes

Over 157 types of dishes were prepared for which there are weighed and recorded ingredients. Each was assigned a unique code. If a dish was prepared while the enumerator was absent, the weight of each ingredient was estimated (recalled). Recipes can appear as ingredients in other recipes that were prepared later in the observation period.

A SAS program was used to provide the nutrient content of each ingredient in a dish, multiply the nutrient values by its weight, and to recompute the volume of each dish to allow for the use of previously prepared dishes as ingredients in the current dish, The nutrient values for all ingredients were then adjusted by the final weight of the cooked dish. A file contains the nutrient values for 100 grams of each household dish.

Development of a Standard Recipe Nutrient Data Base

When a respondent reported consumption of a dish for which no recipe was available (e.g., it was consumed at another house or measurements were not made during preparation), a standard recipe code was used. There are 157 standard recipe codes, corresponding to the 157 household dish codes.

A SAS program was used to calculate nutrient values for standard recipes, based on the median values for corresponding household dishes. Only those dishes for which all ingredients had been weighed (rather than recalled) were used for this calculation. To test the stability of the composition of recipes over time, particularly during the food shortage period, median energy values were examined for ten commonly consumed dishes at three time points (prior to the drought, during the drought, and after the drought). The variation was less than 12 kcal per 100 grams for nine of the dishes, and 41 kcal/100g for a common dish, ugali. Thus, an overall median value for each standard recipe was used.

Validation with Analytic Values

The nutrient content of several mixed dishes was analyzed by Medallion Laboratories using one to three samples each of twelve typical dishes. The analytic values were compared to the corresponding standard recipes. In general, the analyzed and calculated values were within 15 kcal/100g of each other, except for the standard recipe being slightly higher than the analytical values for ugali (stiff porridge) and for chapati (flat bread).

In addition, an international "mini-list" for the core nutrient data, constructed by S. Murphy, D. Calloway, and D. Lien of the University of California, Berkeley, includes values for foods in the USDA food tables that most closely approximate the foods and ingredients used in the Embu diet. Nutrient data were compiled for 48 nutrients and for 10 amino acids.

Calculation of Individual Nutrient Totals

The amount of a food item or dish consumed by an individual was recorded, and coded by meal, dish and if appropriate either as a snack or non-household food item. Non-household food items included not only food eaten outside the home, i.e. relief foods and gifts, but also consumed in the home at any time.

The coding system indicated whether the target individual was not present on a given day. A meal code was also used to indicate that the target individual had no intake on that day.

A SAS program was used to calculate nutrient totals for each individual from multiple sources: the nutrient data base (for single food items), the standard recipe nutrient data base (for foods prepared outside the home and standard recall recipes), and the household recipe nutrient values (for homemade dishes). The corresponding nutrient values per 100 grams are multiplied by the portion size and totalled for each individual, by dish, snack, and non-household nutrients. A flag was used to indicate if a child had been breastfed at least once during the day.

Calculation of Household Nutrient Totals

Total daily household nutrient intake was defined as the sum of:

- The nutrient content of all dishes consumed in the household (minus any amount consumed by guests).
- The nutrient content of all snacks consumed by targets and non-targets.
- The nutrient content of all non-household food consumed by targets and non-targets.

Quality control measures are fully described in the Kenya Nutrition CRSP Final Report, 1987 and by Murphy et al (5).

DESCRIPTION OF THE DIET

The Embu diet in the average CRSP household is characterized by being low in energy and actual quantity, low in fat (animal or vegetable) and extremely low in animal source protein, cows' milk being the main source. Milk is taken mainly in sweetened tea.

The phytate and fiber content of the diet is extremely high. The bulk of the diet is grown by the households for their own use. The principal staple is white maize, complemented by cowpeas and other beans. Millet and sorghum are used much less frequently than maize, and particularly in the drier parts of the study zone. Potatoes and a variety of green leafy vegetables, cabbage, cowpea leaves and *sukuma-wiki* (kale-like leaf) are used almost daily. Seasonally, mango, papaya, avocado and banana are eaten as snacks. Thin gruels of millet, sorghum or maize are eaten extensively by young children and occasionally fermented.

The backbone of the main meal is *githiri*; a boiled stew; consisting of maize, beans, greens and tomato as available. Salt and some fat are added, but rarely is goat meat, beef or any other meat added. Eggs are rarely eaten. As snacks, a variety of insects and grubs, high in fat and protein, are eaten. Rice is purchased by better-off households, as are white bread and wheat flour. Sweetened tea with milk is a common beverage among all age groups. The main "hotel" foods include fried unsweetened donuts, vegetable stews, roast maize, and occasionally roast goat, eaten mainly by the men. Alcoholic beverages include mainly home-made and to a lesser extent commercially brewed beer. Women rarely drink, but men consume an average of a half to one liter per day, based on a cross-sectional survey. Alcoholic intake in men is underreported.

DIET QUANTITY: ENERGY INTAKE

Actual kcal intake per 24 hours and kcal per kg/24 hours were compared to intakes recommended by the FAO/WHO/UNU (10). For toddlers, the estimated mean energy needs are based on kcal per kg body weight, assuming normal rates of growth and normal levels of activity. For adults, the estimated needs are based on basal metabolic rate (BMR) multiplied by a factor representing the increased need for a predetermined level of physical activity; i.e., 1.75 x BMR for moderate activity level.

A problem arises with the assessment of energy requirements in the seven to nine year old schoolers using FAO/WHO/UNU recommendations for estimated level of physical activity and estimated BMR. Using a factor of 1.75 for the estimated activity level underestimates the activity level, based on our observations of the school age children. An activity factor of approximately 2.0 x BMR is more appropriate than 1.75, given the fact that on a daily basis, schoolers walk and often run long distances to school and back, then spend time fetching water and fuel and participating in agricultural work after school. Their observed level of energy intake is 1509 kcal for boys and 1344 kcal for girls. The schoolers are not only stunted but generally thin and underweight for height.

A summary of energy intake and adequacy relative to recommended intakes is presented in Table 2.1 below. All target groups were considerably below recommended intakes. Using the 1985 FAO/WHO/UNU recommendations, men, pregnant and lactating women, and then toddlers (in descending order) were the most energy deficient. The schoolers fared slightly better than the men in terms of energy adequacy. Even if the men's observed intake is underestimated, they are thin, with a mean z-score of -1.6 for weight and a mean BMI of 20.0 or z-score -1.41, with 52% of men below a BMI of 20.

There does not appear to be gross systematic nutritional neglect of females in the toddler or schooler age groups or in adulthood. However, female schoolers, did have consistently poorer intakes relative to their weight than did male schoolers (approximately 74 kcal/kg for boys and 67 kcal/kg for girls).

There may be two possible explanations for the possible under-estimation of observed intakes in men. The men ate more of their midday meals away from home than any other of the family members, and may not have recalled their intake accurately or not reported it to their wives. Also, the men underreported their alcohol intake. On the regular food intake procedure, 17% of men reported alcohol intake but by confidential questionnaire 53% admitted to drinking a liter (2 pints per day). Overall, this level of drinking would increase mean male energy intake about 200 kcal/day based on measured energy composition of the beers consumed in the study area (estimated by D. Calloway).

TABLE 2.1
Energy and macronutrient intakes and mean percent of recommended energy allowance over the entire study (mean ± SD)

	Men	Women			Schoolers		Toddlers	
		NPNL	Preg	Lact	Boys	Girls	Boys	Girls
No. subjects	237	225	152	149	75	60	52	55
No. observations	7758	8202	--	--	2151	1791	1495	1607
Energy (kcal/d) (M)†	1924	1762	1442	1749	1509	1344	840	805
(SD)†	409	375	420	459	239	209	165	146
Protein (g/d)	60	51			45	40	23	21
	34	28			22	19	15	14
Animal Protein	5.0	3.9			2.7	2.5	3.1	3.9
	11.4	8.1			5.8	4.6	5.6	6.5
Fat (g/d)	31	26			22	20	13	14
	20	17			12	11	11	11
Carbohydrate (g/d)	388	338			300	269	166	156
	199	166			131	121	98	88
% kcal: fat*	14.0	13.7			13.1	13.3	13.9	15.7
% kcal: carb.*	77.8	79.0			79.3	79.3	79.0	77.5
% kcal: prot.*	12.0	11.9			11.9	11.8	10.9	10.4
% kcal an prot*	8.3	7.6			6.0	6.3	13.5	18.6
% RDA‡	66.4	81.9	57.7	64.8	78.1	78.5	73.1	70.0

* Kcal calculated roughly as fat, gx9; carbohydrate and protein, gx4. Energy intakes have been calculated from the nutrient data base, which uses specific energy values appropriate to the food; i.e., taking account of composition and digestibility.
† M = mean, SD = standard deviation
‡ FAO/UNU/WHO 1985.

DIET QUALITY

There are several important dimensions to the problem of poor diet quality. When the quantity of food intake is low, all nutrients are apt to be low, as is the case in the Kenya CRSP diet (see Table 2.3). Fat is an excellent source of compact kcals and is supplied mainly by vegetable fat. Diet quality is also judged by the extent to which a given diet supplies specific nutrients, mainly micronutrients, in absorbable and bio-available form, particularly iron and zinc. As discussed below, the Embu diet is very low in the actual intake of animal protein and the percent of kcals from animal protein, especially heme protein (meat, fish, fowl). Animal protein intake not only has intrinsic nutritional value as an excellent protein source, but also serves as a marker for other nutrients.

Adequacy of Protein Intake and Amino Acid Scores

Comparing dietary intake of protein and the amino acid content of the protein to recommended values by FAO/WHO/UNU (4), no group is seen to be deficient in protein or to have a limiting amino acid in the diet (11). Further evaluation of the adequacy of the diet for protein and amino acids is based on the "probability approach" and was carried out by Beaton, et al (11).[2] From examination of the apparent prevalence of inadequate protein intake and assessment of protein/energy (P-E) ratios and dietary and clinical correlates, protein intakes were not found to be limiting except for a few toddlers. Protein is estimated to be 90% of the recommended intake in the Embu diet, a diet low in animal source foods. Protein utilization is estimated at about 78% of total protein intake (1).

Protein Digestibility

The general type of diet consumed by the Kenyan study population, comprised mainly of maize and beans, was rated at a digestibility of 82% by FAO (7) (see Table 2.2). Digestibility for adults and schoolers is 83.1 to 83.5%, and for toddlers, 84.4 to 85.4%. These values are slightly above those recommended (82%), for toddlers.

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[2]This method was applied for estimation of protein and mineral adequacy of the diet by Beaton, Calloway, and Murphy et al. (1992).

TABLE 2.2.
Digestibility of animal, plant and total protein based on FAO estimates of diet type* (4)

	Adults		Schoolers		Toddlers	
	M	F	M	F	M	F
% animal protein	8.3	7.6	6.0	6.3	13.5	18.6
% plant protein x .82	75.2	75.8	77.1	76.8	70.9	66.8
Total % digestibility	83.5	83.4	83.1	83.1	84.4	85.4

* Table from G. Beaton et al (11).

Amino Acid Scores

The amino acid pattern was found to be generally acceptable, except for lysine and tryptophan levels, which were somewhat below the reference pattern. Lysine would be the most potentially limiting amino acid in this maize-based diet. Beaton et al (11) calculated the amino acid (AA) scores based on the FAO/WHO/UNU guidelines to be as follows: 70% for toddlers, 90% for schoolers, and 100% for adults.

Adjusted Dietary Protein Requirement Estimates

In light of the information on protein digestibility and the AA scores, the protein requirement for Kenyan toddlers was estimated to be 1.61 ± 0.17 g/kg/day; for schoolers, 1.10 ± 0.14 g/kg/day; and for adults, 0.73 ± 0.09/kg/day (11).

Since total food intake was low, e.g., the toddlers' 82.7 kcal/kg/day in comparison to the FAO/WHO/UNU recommended intake of 103 kcal/kg/day, just increasing energy intake to the estimated level for energy requirements would provide adequate protein for all but a few toddlers. However, because of the insecure nature of the food supply, as in a period of drought with a precipitous drop in food intake, inadequate protein intake could develop quickly. During the 1984 food shortage, a number of children in the study area developed frank clinical signs of kwashiorkor.

Specific Nutrient Intake

For all age groups the most consistently diminished intakes are for overall energy and for zinc, vitamin B_{12}, iron (except in men), riboflavin, and calcium. Vitamin A and niacin are generally low, but not to the degree of the above mentioned nutrients. During pregnancy, energy intake falls dramatically. Folate and pyridoxine also fall below the recommended levels of intake. Clinical correlates of the above low intakes are reflected in microcytic and macrocytic anemia and clinical signs of B-vitamin deficiencies, especially riboflavin. Fifteen percent of the study sample was noted to have angular stomatitis, cheilosis, and/or a smooth atrophic or magenta tongue. Clinical signs of vitamin A deficiency or rickets were not seen.

Iodine deficiency is present in the area and discussed in more detail in a later section. Goiter is present in about 8% of children and 24% of pregnant women. The Embu water is low in iodine concentration; therefore, food consumption tables would understate the problem of iodine deficiency in foods grown in soil that has very low iodine content.

In general, intake of specific nutrients is tied to total energy intake. This is demonstrated by Table 2.3 where the percent of individuals in each major age group who have *no* deficient intake of iron, iodine, or vitamin A are presented below by level of energy intake.

TABLE 2.3
Percent of individuals in each age group with normal iron, iodine, and vitamin A intakes

	Levels of energy intake			
	Total group at or above RDA*	Those at ≥ 80% RDA	Those at ≥ 67% RDA	Those at <67% RDA
	%	%	%	%
Men	12.7	15.0	16.0	9.2
NPNL women	0	0	0	0
Pregnant	0	0	0	0
Lactating	0	0	0	0
Schoolers				
Male	9.3	21.0	14.6	0
Females	1.7	6.3	2.3	0
Toddlers				
Male	9.6	25.0	16.7	0
Females	3.6	22.2	7.4	0

*RDA for energy FAO/UNU/WHO Tech. Series Report 724 (3), FAO Tech Report No. 23 (12).

It is striking that for the above nutrients, so few Kenyans are ingesting amounts above the recommended intakes. Males, both schoolers and adults, do the best in this regard and women do the worst of all. As energy intake declines below 2/3 of the recommended intakes, the percentage of people with deficient intakes of specific nutrients increases.

"Adequacy" of the Diet in Meeting Recommended Dietary Intakes[3]

The nutrient adequacy of the Embu diet is based on comparisons of observed intakes of nutrients compared to recommended intakes based on several sources. The WHO Technical Report Series No. 724, 1985 for Energy and Protein; FAO Food Nutrition No. 23 for vitamin A, B_{12} and folate; and the National Research Council Recommendations for International Agencies in Wood-Dalstrom and Calloway (13), are felt to be most appropriate for Kenya. Nutrient intakes are presented by age groups, sex and reproductive states of women in Tables 2.4 to 2.7. The data is presented as percents of recommended intake levels and percent below two-third of the recommended level.

The nutrient values represent averages of mean individual intake for the entire period of observation.

toddlers--12 mos.	lactating women--6 to 8 mos.
schoolers--12 to 18 mos.	pregnant women--7 to 9 mos.
lead males--12 to 24 mos.	NPNL women--12 to 24 mos.

Two measurements of daily food intake per month (contiguous days) were averaged to represent a usual month's intake. Nutrient values represent means of the individual intakes for the entire period of observation.

[3] Analyses of nutrient adequacy was supported by a mini-grant from World Bank, (Dr. J. McGuire).

TABLE 2.4
Nutrient distribution for Embu toddlers: male (n = 55) and female (n = 58)

Nutrient	Cutoff	Mean ± SD		% below cutoff	% below 2/3 cutoff
Vitamin A (μgRE)	M 400	377	264	66	26
	F 400	326	142	75	47
Vitamin C (mg)	M 20	47	19	7	2
	F 20	44	16	3	0
Thiamin (mg)	M 0.5	0.7	0.1	12	2
	F 0.5	0.6	0.2	19	2
Riboflavin (mg)	M 0.8	0.5	0.2	98	53
	F 0.8	0.5	0.2	93	60
Niacin (mg)	M 9.0	6.1	1.3	100	47
	F 9.0	5.6	1.3	98	62
Pyridoxine (mg)	M 1.0	0.9	0.2	73	11
	F 1.0	0.9	0.2	69	16
Vitamin B_{12} (μg)	M 0.5	0.7	2.0	75	55
	F 0.5	0.4	0.3	71	43
Folate (μg)	M 50	190	60	2	2
	F 50	165	49	0	0
Calcium (mg)	M 450	193	85	100	89
	F 450	213	108	97	86
Iron (mg)	M 9.0	7.0	1.6	78	24
	F 9.0	6.2	1.7	90	35
Zinc (mg)	M 16	3.6	0.8	100	100
	F 16	3.3	0.9	100	100

TABLE 2.5
Nutrient distributions for Embu schoolers: male (n = 70) and female (n = 62)

Nutrient	Cutoff	Mean ± SD		% below cutoff	% below 2/3 cutoff
Vitamin A	M 500	489	188	59	24
(μgRE)	F 500	500	186	61	17
Vitamin C	M 20	61	22	1	0
(mg)	F 20	66	25	0	0
Thiamin (mg)	M 0.9	1.4	0.3	1	0
	F 0.9	1.3	0.2	2	0
Riboflavin	M 1.3	0.8	0.1	100	59
(mg)	F 1.3	0.8	0.1	100	77
Niacin (mg)	M 14.5	12.1	2.0	88	9
	F 14.5	11.0	1.8	98	24
Pyridoxine	M 1.4	1.4	0.3	54	1
(mg)	F 1.4	1.3	0.3	76	11
Vitamin B_{12}	M 0.9	0.3	0.3	96	87
(μg)	F 0.9	0.4	0.7	97	97
Folate (μg)	M 102	385	98	0	0
	F 102	250	76	0	0
Calcium (mg)	M 450	228	68	100	84
	M 450	225	57	100	90
Iron (mg)	M 16	15.3	2.7	55	1
	F 16	13.6	2.4	81	8
Zinc (mg)	M 16	7.6	1.3	100	100
	F 16	6.7	1.3	100	100

TABLE 2.6
Nutrient distributions for Embu adults: men (n = 246) and NPNL women (n = 153)

Nutrient	Cutoff	Mean ± SD		% below cutoff	% below 2/3 cutoff
Vitamin A	M 600	566	249	65	24
(μgRE)	F 500	514	297	57	30
Vitamin C	M 30	69	28	3	0
(mg)	F 30	68	37	4	1
Thiamin (mg)	M 1.2	1.8	0.4	13	2
	F 0.9	1.7	0.5	2	1
Riboflavin	M 1.8	1.1	0.3	100	68
(mg)	F 1.3	1.0	0.2	91	25
Niacin (mg)	M 19.8	15.2	3.5	92	27
	F 14.5	14.2	3.7	60	9
Pyridoxine	M 2.0	1.7	0.4	77	18
(mg)	F 1.6	1.6	0.4	59	8
Vitamin B_{12}	M 1.0	0.6	0.6	80	65
(μg)	F 1.0	0.5	0.9	90	78
Folate (μg)	M 200	497	145	1	0
	F 170	503	198	2	1
Calcium (mg)	M 450	329	112	84	46
	F 450	298	109	90	55
Iron (mg)	M 15.5	19.3	4.8	20	3
	F 32.0	17.8	4.6	100	77
Zinc (mg)	M 22.0	9.7	2.2	100	100
	F 22.0	8.9	2.2	100	98

TABLE 2.7
Nutrient distributions for Embu women: pregnant (n = 164) and lactating (n=152)

Nutrient	Cutoff	Mean ± SD		% below cutoff	% below 2/3 cutoff
Vitamin A (µgRE)	P 600	488	334	74	48
	L 850	377	264	65	25
Vitamin C (mg)	P 30	70	39.1	12	4
	L 30	46	19	7	3
Thiamin (mg)	P 1.0	1.3	0.5	23	4
	L 1.1	0.7	0.1	13	3
Riboflavin (mg)	P 1.5	0.8	0.2	99	78
	L 1.7	0.5	0.2	98	53
Niacin (mg)	P 16.8	11.4	3.8	93	56
	L 20.0	6.1	1.3	100	48
Pyridoxine (mg)	P 2.2	1.4	0.5	90	60
	L 2.1	0.9	0.2	73	11
Vitamin B_{12} (µg)	P 1.4	0.4	0.4	97	92
	L 1.3	0.7	2.0	75	55
Folate (µg)	P 370	384	178	56	23
	L 270	190	60	3	3
Calcium (mg)	P 1100	253	102	100	100
	L 1100	193	84	100	89
Iron (mg)	P 32.0	13.6	4.7	99	95
	L 30.0	7.0	1.6	78	24
Zinc (mg)	P 30.0	6.8	2.3	100	100
	L 19.0	3.6	0.8	100	100

Correlates of Adequate Intake

As noted earlier the Embu diet is very low in the actual intake of animal protein. Animal protein intake serves as a marker for other nutrients, namely iron, zinc and vitamin B_{12}. In support of this, correlations between animal protein intake and zinc, iron, fat, and vitamin B_{12} in all women are presented in Table 2.8.

TABLE 2.8
Relation between animal source protein and MPF* protein with diet quality variables

			r	p
Animal protein (g/d)	vs	Zinc	.24	.0002
	"	MPF (meat, poultry, fish)	.82	.0000
	"	Iron and ferritin)	NS	
	"	Kcal	.19	.003
	"	Fat	NS	
	"	Hg	.11	.11
	"	Vitamin B_{12}	.78	.0001
Total kcal	vs	Iron	.90	.0001
	"	Zinc	.94	.0001
	"	Vitamin B_{12}	.17	.01

*Meat, poultry and fish

Animal source protein and micronutrients also correlate positively with SES, as does fat. These items are mainly purchased with cash. Poverty, lack of education, and the "modernity score," are important determinants of animal protein and fat intake (see Table 2.9).

TABLE 2.9
Socioeconomic correlates of animal protein and fat intake (n = 247 women)

			r*	p
Animal protein n = 237	vs	SES	.36	.01
		Modernity†	.52	.01
Fat Intake			.39	.05

* Pearson's correlations (2-tailed, $p < .05$)

† Variable comprised of use of bank, post office, telephone, agricultural innovations and newspaper

These correlations suggest that by increasing the amount of energy in the diet (food quantity), the micronutrient levels would increase. High phytate and fiber content of the diet and high consumption of tea also contribute to poor zinc and iron bioavailability.

Iron

According to observed values, deficient iron intake is widespread in all study groups except in the men. This assessment does not take into account the low bioavailability of iron and the presence of hookworm, which may diminish the amount available for absorption from the intestinal tract (see Table 2.10).

TABLE 2.10
Observed iron intake compared to recommended intakes* (mg/day)

	Recommended intake (mg/d)	n	Observed intake mean ± SD	% below Rec'd intake	% below 2/3 of rec'd intake
Men	20	246	19.3 4.8	20.3	3.3
Women					
NPNL	15	237	17.8 4.6	100	77.2
Pregnant	30	164	13.6 4.7	99.4	94.5
Lactating	30	152	17.8 5.6	99.3	77.0
Schoolers					
Male	15	75	15.3 2.7	55.3	1.3
Female	15	60	13.6 2.4	80.6	8.1
Toddlers					
Male	9	52	7.0 1.6	78.3	23.6
Female	9	55	6.2 1.7	89.7	34.5

* FAO/WHO/UNU (10) and NRC (13).

The diet classification based on the amount of heme protein, ascorbic acid, fiber and phytate in the diet is considered low in iron bioavailability. Although vitamin C is not low in the diet, it is often eaten as a snack between meals, about once per day. Using the FAO classification for estimating dietary iron requirements, the following recommended values are shown in Table 2.11.

TABLE 2.11
Recommended iron intakes to prevent anemia and satisfy all needs for iron

	To prevent anemia (mg/day)		To satisfy all functions and storage (mg/day)	
	mean	± SD	mean	± SD
Toddlers	6.5	0.9	9.8	1.4
Schoolers	12.5	1.9	18.8	2.8
Adults (M)	12.1	1.9	18.2	2.8

Iron intakes to prevent anemia, but not to build up iron stores, are inadequate in about 80 to 95% of women and children and in about 53% of men. About half of each group does not receive enough iron to "stabilize" mild iron deficiency. To aggravate the problem of poor iron intake, hookworm infection is prevalent in the area. Forty-eight percent of men's stool specimens were positive for hookworm ova, as were 55% of women's specimens. For the children, 36% of schoolers and 6% of toddlers had stools positive for hookworm infection. Using chi-square analyses, there is a significant relationship between hemoglobin level and hookworm infestation (chi-square = 38.6, $p < .000$) in schoolers and toddlers.

Evaluations of iron adequacy using both the conventional method of comparing observed intake to recommended intake and the probability assessment method for meeting basal needs, yield similar results.

Serum ferritin is an indicator of iron stores and is low in all groups except the men. However, one problem with using serum ferritin as an indicator of iron stores is that elevated levels are seen in the presence of infection and liver disease, thereby masking deficient iron stores. Both these conditions are prevalent in Embu. In particular, hepatitis is widespread in the area.

Based on high percentages of low hemoglobin and hematocrit levels, erythrocyte microcytosis and hypochromia, low serum ferritin, low iron intake, and hookworm infection; iron deficiency is widespread. There is a discrepancy in the estimate of iron deficiency based on hemoglobin compared to an estimate based on serum ferritin or microcytic anemia. The latter gives a lower prevalence of iron deficiency than one based on hemoglobin levels. This is due, no doubt, to the fact that other causes of anemia, such as malaria, low B_{12}, and folic acid deficiency in pregnancy are also present. Also macrocytosis can mask the microcytic changes in erythrocytes. Ferritin and hemoglobin levels are presented in Table 2.12.

TABLE 2.12
Serum ferritin and hemoglobin levels in different age groups

		Serum Ferritin (ng/ml)		% below cutoff (<10 ng/ml)	Hb level		% below cutoff for anemia*	% with Hookworm (pre-Rx)
	n	mean ±	SD	%	mean ±	SD	%	%
Men	237	76.5	87.0	10	14.9	1.8	5	48
Women								
NPNL	142	26.8	43.3	35	12.2	1.8	34.5	55
Pregnant	124	23.2	26.2	35	11.4	1.7	37	
Lactating	94	37.8	42.2	15	12.2	1.5	40	
Schoolers								
M and F	123	35.7	39.3	22	12.1	1.5	43	36
Toddlers								
M and F	90	19.2	24.4	42	10.7	1.7	60	6
Infants								
M and F	72	37.1	43.0	18	10.9	1.8	34	0

* 12 gm/dl; men, NPNL and lactating women, schoolers
11 gm/dl; pregnant women, toddlers, and infants.

Zinc

To date, zinc deficiency has not been reported to be a problem in Kenya. The widespread stunting in Kenya has always been ascribed mainly to protein energy malnutrition (PEM) and infection. Also the diet in many parts of Kenya, as in Embu, is maize-based, with little animal protein eaten.

Based on dietary intake information, zinc intake is very low. Nearly 100% of all groups studied are below 2/3 of the intake levels recommended by WHO/FAO/UNU (7). This is due to the low intake of animal foods especially protein from meat, poultry or fish. In addition, zinc bioavailability is greatly reduced by the presence of phytate and fiber, particularly phytate, which is high in the Embu diet, 1600 to 2200 grams ingested per day. A favorable phytate:zinc molar ratio for zinc absorption is considered to be 10. The phytate:zinc molar ratio in the Embu diet is over 20 (14). Moreover, the fiber intake is over 50 g/day compared to the 13 g/day in USA diets. Net zinc bioavailability is about 10%.

Sera from a very small subsample of men and women were tested for zinc levels. Capillary blood samples were obtained using zinc-free lancets and capillary tubes and analyzed using micro-methods[4] according to the method of Mohs (4). Because of the inadequate quantity of sera in some samples, these samples had to be pooled. Results are shown in Table 2.13.

TABLE 2.13
Serum zinc levels on a small sub sample of Kenyan adult men and women

	Adult Males	Adult Females	
	n = 7	NPNL n = 7	Lactating n = 4
Mean ± SD (mg/dl)	81.1 ± 78.0	85.7 ± 75.8	79.3 ± 92.5
Percent low*	42.8 (3/7)	14.2 (1/7)	25.0 (1/4)

* Serum zinc range: 55-150 mg/dl. USA ( ).

A probability assessment in the toddlers performed by Murphy et al confirms the findings of a zinc deficiency problem (14). The predicted prevalence of inadequate zinc intake to satisfy both "normative" requirements is 97%, and for "basal" requirements, 74.9%. Feeding more of the same diet would not appear to solve the problem as it might for iron. An increase in animal source protein and a decrease in phytate and fiber intake are needed. Fermentation of grains could accomplish a decrease in phytic acid.

Based on preliminary analyses, a functional consequence of low zinc was seen on the toddlers' linear growth and on intrauterine growth (see Chapters Four and Five). Observed zinc intake related positively and phytate negatively to toddler length, even when controlling for kcal intake. Using an algorithm for bioavailable zinc, a positive effect of zinc on growth in toddlers was found.[5] Also, length at birth in the infant cohort related positively to maternal pregnancy zinc intake.

To complicate the issue of low zinc intake and linear growth in the children, iodine deficiency and chronic low energy intake, B_{12}, calcium deficiency, and infection all coexist and may also play a role in stunting. Only a well-controlled double blind study involving

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[4] Zinc analyses were carried out by S. Carlson and Dr. E. Castro, UCLA School of Public Health. The method was devised by Dr. Mary Moh. Zinc status and functional correlates in preschool and school age children in Egypt (doctoral dissertation, University of Arizona, 1989).

[5] Algorithm developed by S. Murphy, D. Calloway, and D. Lien, University of California, Berkeley.

pregnant women and toddlers might answer the question of the role of zinc deficiency in stunting. Zinc deficiency also plays a role in cell-mediated immunity, an important factor in morbidity. This analysis has not as yet been carried out.

Iodine Deficiency

Mild iodine deficiency (IDD) is present in the Embu area as suggested by 8% goiter prevalence in schoolers, 24% in pregnant women and 20% in NPNL women. When 10% of a given population exhibit goiter, iodine deficiency is considered a public health problem in that community (16). The water supply derives from melted snow and ice from Mt. Kenya, which flows downhill in streams and small rivers, leaching out soil iodine. Water levels measured in 8 different water sources throughout the study area were all considered low. Only 27% of household reported iodized salt use, and in these households, iodized salt was used less than 50% of the time. The mean iodine intake per household was 5.1 grams/day.

Iodized salt use showed significant associations with SES, literacy and "modernity" (a composite index of reading of newspapers, post office, telephone and bank usage). Families queried about the use of iodized salt stated that it was too expensive to buy.

The diet contains no sea products or fish and is comprised mainly of food grown in local soil. Goitrogens such as cabbage, cassava, and possibly *sukuma-wiki* are also eaten. Measurements of thyroid hormones and TSH in a subsample of adults show that 8-11% have low thyroid hormone levels and about 11% have elevated TSH levels. Thyroid hormone levels relate positively to iodized salt use and negatively to TSH, the latter being an early indication of thyroid insufficiency. Functional effects of iodine deficiency are described in the chapters on Stunting (Five), Cognitive Outcomes (Six), and Reproductive Function (Four).

Familial Concordance of Thyroid Hormone Levels

It would be expected that members of a given household, using the same water and food supply and salt supply, would be similarly affected in regard to thyroid status. Salt is added to the family food cook pot and not to individual portions. Positive and statistically significant correlations were found in thyroid hormones, between spouses, between parents and their children, and between siblings ($r = .18$ to $.82$, $p < .05$ to $.000$). The elevated TSH levels are a sign of hypothyroidism or low thyroid hormone levels (see Table 2.13).

TABLE 2.13
Familial concordance of thyroid hormone levels

	n	r*	p
Between Spouses			
Male FT4 vs. Female FT4	168	.18	.02
Between Mother and Children			
TSH vs. Toddlers T4	47	-.28	.05
vs. Schoolers TSH	118	.28	.002
FT4 vs. Toddlers TSH	47	-.26	.07
vs. Infants FT4	25	.35	.08
vs. Infants T3	15	.59	.02
Between Father and Children			
TSH vs. Toddlers T4	47	-.28	.05
T4 vs. Schoolers T4	110	.25	.009
vs. Toddlers T3	33	.47	.008
FT4 vs. Toddlers T4	19	.25	.08
vs. Toddlers FT4	49	.25	.08
Siblings			
Toddlers TSH vs. Infants T4	6	-.82	.04
vs. Infants FT4	6	-.78	.07
Toddlers FT4 vs. Schoolers T3	13	.58	.04

* Pearson's correlations (2-tailed) ($p < .05$).

Vitamin B_{12} Deficiency

Vitamin B_{12} intake was found to be very low in all target individuals, but lowest of all in pregnant/lactating women in terms of percent RDA consumed. The mean percent of inadequate intake (<2/3 RDA) ranged from 43% in toddlers to 91% in pregnant women.

As noted above, the diet is very low in animal products, the main source of vitamin B_{12}. Animal protein comprises only 4 to 12 g/day or 12% of kcals in the diet. Milk is the main source of animal protein. It is not known how much, if any, B_{12} is synthesized in fermented gruels, which are used occasionally in this area. Fermented maize, millet, and sorghum are the main fermented grains used.

Clinical evidence of B_{12} deficiency consists of the presence of macrocytic anemia in 9% of women, 12% of toddlers, and 3% of men. About 4% of women also show hyper-segmented polymorphonuclear (PMN) cell nuclei, a sign of B_{12} deficiency. Folic acid intake, also a cause of megaloblastic anemia, was found to be deficient in 23% of pregnant women and 4% of lactating women, but in only a negligible percentage of other targets groups.

Corroborating evidence for vitamin B_{12} deficiency comes from analyses of breast milk levels.[6] The mean levels found were considered very low. Analyses of 294 breast milk samples from 98 women, randomly collected in the morning, were carried out. Each woman had three samples analyzed, starting at one week of lactation to the sixth month of lactation. Vitamin B_{12} was measured by a competitive binding isotope dilution technique. With few exceptions, B_{12} levels were very low compared to breast milk values measured by the same method in non-supplemented, well-nourished American women. Kenyan values were slightly higher than those for low-income vegetarian Indian women (80 pg/ml) (17) (see Table 2.14).

Of interest is the fact that the B_{12} content of the first of each of the women's 3 breast milk samples was significantly higher than the levels obtained 1 to 4 months later.

TABLE 2.14
B_{12} levels in breast milk of rural Kenyan women collected from 0 to 6 months post-natally*

B_{12} levels (pg/ml)	Overall B_{12} level mean	± SD	Early lactation (0-1 mos.) mean	± SD	Lactation (1-4 mos) mean	± SD
Kenyan Women	165	10	237	18	131	18
USA Women	605	185	1220	410	610	170

* 500 pg/ml is considered the cutoff in breast milk for low values.

The decreased values of B_{12} concentration in breast milk seriously limits infants' B_{12} intake, particularly at a time when somatic and CNS growth is most rapid. Functional expression of infant B_{12} deficiency is being explored in relation to physical and cognitive development. Some effects on infant growth are reported in Chapter Four. A correlation between maternal B_{12} intake and breast milk B_{12} levels obtained between one to four months is $r=.49$, $p < .04$ ($n = 19$) (Pearson's, 2-tailed).

[6] B_{12} levels in breast milk were analyzed by Dr. S. Oace, University of California, Berkeley.

SUMMARY

The analysis of the food intake situation has been possible only through the collection of high quality data, using an excellent methodology by well-trained, well-supervised field staff. The collaboration with the Nutrition CRSP group at the University of California, Berkeley, in constructing a nutrient data base for the Embu diet, was invaluable. An important contribution of the Nutrition CRSP is that Kenya now has a painstakingly constructed nutrient data base which will serve not only Embu but Eastern province and similar regions in Kenya and contiguous countries as well. Field workers trained in the methodology have been utilized by other research groups working in Western Kenya and Turkana, for example.

A major finding of great importance is that the diet is not only low in energy in all age groups, but of poor quality, with micronutrient and vitamin deficiencies. Vitamin B_{12} and zinc deficiencies have not been previously recognized in Kenya.

Based on food intake information and analysis of the diet; zinc, B_{12}, iron, and iodine, as well as other B-vitamins riboflavin and calcium, are lacking in the diet. Biochemical, hematologic, and clinical evidence confirms that B_{12}, iodine, and iron deficiencies exist. Low riboflavin intake is confirmed by clinical findings of signs of B-vitamin deficiency in 15% of the sample. Intervention studies are needed to confirm the above conclusions.

Although more must be learned about the foods and their nutrient content, there is sufficient information for nutrition education and intervention. Eating more of the same diet will solve the energy problem and in part the iron problem, but not the B_{12}, iodine, or zinc problems, as the basic diet is very low in these nutrients to begin with. Iodized salt availability, affordability and distribution must be assured by government. Approaches to improving the quantity and quality of the diet and food security are discussed in the chapter on Drought, and in the final chapter on Policy and Program Implications (Chapters Nine and Ten).

A very large problem is that of nutritional anemia. Compounded by malaria and hookworm; iron deficiency, B_{12} deficiency, and possibly folate deficiency in pregnancy cause the anemia. Sickle-cell anemia is not a problem in the area. Functional consequences of anemia are currently being examined, particularly in the mother in regard to ability to care for the children and perform household, agricultural and other work. Cognitive function and school behavior is another area of concern in relation to iron deficiency anemia. Thus, iodine, iron and zinc deficiency and B_{12} may all be confounders in trying to further tease out the functional consequences of energy deficiency, particularly on growth, cognitive development, immune function and physical work. Based on the dietary findings alone, an intervention can be planned.

The overall challenge is to improve the quantity and quality of the diet through community efforts and resources and then to educate people to change some of their nutrition and feeding practices, particularly during pregnancy, lactation and for young children. All age

groups would benefit from an improved diet. However, a high priority would be to prevent and reverse stunting. Schoolers also would derive more benefit from their education if they were better fed.

The problem of periodic food shortage and food security is dealt with in Chapter Nine.

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CHAPTER THREE.
MORBIDITY

INTRODUCTION

Morbidity, particularly of infectious origin, is not only an important outcome in relation to food intake but a determinant of food intake, nutrient utilization and nutritional status. Illness is thus an important intervening or modifying factor in all functional outcomes measured in the Nutrition CRSP studies.

This chapter will present an updated description of the morbidity picture and analyses since the 1987 Kenya Nutrition CRSP Final Report. The relationship of food intake, nutritional status and household factors to morbidity are examined. In addition, this chapter will present analyses on the impact of infectious disease on food intake in children, and on nutritional status; namely attained size and rate of growth, and pregnancy weight gain. Related analyses in the chapter on Cognitive and Behavioral Outcomes (Chapter Six) show that morbidity, per se, has a negative effect on cognitive development in young children and on cognitive function and school performance in older children. It was also shown in the 1987 Final Report that intake of energy and specific nutrients and nutritional status negatively affect cell-mediated immune function. Chronic disease and household morbidity, although data are available, have not yet been analyzed in relation to food intake or other nutritional factors.

Of particular relevance to morbidity is that the 60 sq km study area includes a mission hospital, a health center with a small maternity and children's ward, and several dispensaries for treating minor illnesses. These health facilities are within 5 to 10 km of most households and are mainly reached by foot. As this is a site for the Expanded Programs for Immunization (EPI), immunization coverage for eligibles was over 90% for DPT and BCG and 83% for measles.

METHODS

Brief Review of Morbidity Data Collection Methodology

Methods for morbidity data collection have been thoroughly described in the 1987 Kenya Nutrition CRSP Final Report and are summarized here. Morbidity information was obtained during weekly visits to each household, using a structured illness questionnaire and physical inspection. The caregiver, usually the mother, or another informant was asked about any illness or symptoms the household members had experienced on the day of the visit and/or in the previous six days. A check list of general categories of illness, and specific signs and symptoms under each category, was used to record morbidity. Any observations relevant to the reported illness and the start and end dates were recorded. Also noted were the source, provider, and the type of treatment received, if any. Continuing illnesses were queried about in the subsequent week in order to record their end dates or determine whether they were ongoing. In cases of puzzling, potential, or actual serious illness, the supervising nurse and/or physician visited the individual and decided if and when a follow up visit sooner than a week or immediate intervention and/or referral were indicated.

As a quality control measure, 5% of the morbidity interviews were repeated several hours later on the same day by a different enumerator and supervising nurse and/or physician. The percent of agreement on specific findings and/or the general category of illness was calculated and found to be 95%. A nurse or physician also accompanied each of the enumerators once per week to observe their performance and spot check their findings.

Morbidity Information recorded for each weekly visit was coded into four-week summaries by the physician and/or nurses. Illness was classified into one of 15 general categories such as eye, respiratory, gastrointestinal, communicable, etc. Each general category was then further divided into specific conditions. The specific disease category was determined from reported and observed signs and symptoms recorded on the weekly forms, and from information on clinic or hospital records and laboratory tests if the subject visited a medical care facility. In coding, the most clinically unifying diagnosis was determined by the physician and nurses. Each illness episode was coded as mild or severe based on predetermined criteria used by all three of the Nutrition CRSP projects. Start and end dates of illness were recorded, permitting calculations of illness duration and wellness periods.

Examples of mild and severe illness are as follows. Diarrhea is defined as $\geq$ 3 watery stools per 24 hours. Mild diarrhea is defined as watery stools without fever, vomiting or dehydration. Mild febrile illness is defined as fever $\leq$101°F. The severe illness category included such communicable diseases as measles; lower respiratory illness (bronchitis, bronchiolitis and pneumonia); severe diarrhea ($\geq$10 stools/day and/or few watery or bloody stools with dehydration); high fevers (>101°F) and clinical or proven malaria.

Morbidity is presented according to the exact reproductive status of the target females pregnant, non-pregnant, and non-pregnant non-lactating (NPNL). This was mainly accomplished by working back from the birth dates of newborns and then using their gestational age, measured by the Dubowitz test, to pinpoint the approximate date of conception (1). The last menstrual periods cannot be relied upon, as many of the women do not menstruate because of a continuous cycle of repeat pregnancies and lactation.

Reanalyses

Since first presented in 1987, the descriptive morbidity data has been reanalyzed to correct the denominator (population at risk), in order to assure that missed home visits were not equated with wellness or absence of illness. Fortunately, there were few missed visits. This circumstance was most common for the lead males who were, at times, away for several days to weeks. Corrections were made for 1984 through review of field records. A new system was put in place in 1985 which eliminated this difficulty.

Overall, the morbidity data set is a valuable one, offering information on acute weekly morbidity, quarterly chronic morbidity, and bi-annual physical and laboratory examinations for physical status on all target individuals. Such consequences of morbidity as change in food intake and activity and task reallocation were also recorded. Relatively few longitudinal morbidity surveys on individuals and total households exist in Africa. Although not identical, parallel methods have been used in the companion Nutrition CRSPs (Egypt and Mexico), enabling valuable cross-country comparisons to be made in terms of relative frequency and impact of illness on function.

DESCRIPTIVE FINDINGS

The following descriptive findings are an update and modification of those in the 1987 Kenya Nutrition CRSP Final Report.

Incidence Rate

Illness incidence rate is defined as the number of new illness episodes in a specified period of time. The denominator is the sum of the person-time at risk for the cohort during the specified period.

Children

Among the children's cohorts, the highest illness rates were found in the 18 to 30 month age group with rates for females slightly higher than for males. The next highest incidence was found in the 0 to 6 month infant group, with no gender differences seen. In school children aged 7 to 9 years, the illness incidence is about half of the toddler incidence rates. The relatively high illness incidence among the infants was unexpected (see Table 3.1).

TABLE 3.1.
Incidence rates for all illness in the children's cohorts (illness episodes per person-week and person-year)

Target Individual	n	Illness episodes	No. weeks observed	Incidence Rates person-wk	person-yr
Male schoolers	74	551	54.3	0.137	7.1
Female schoolers	60	446	56.0	0.133	6.9
Male toddler	53	657	47.7	0.260	13.5
Female toddler	57	858	47.9	0.314	16.3
Male infant	76	453	24.6	0.242	12.6
Female infant	60	350	24.6	0.237	12.3

Adults

In the adults, incidence rates range from 7 to 17 episodes per person, per year in the various groups. Overall, mild illness incidence in women is double that of men, 13 per year vs. seven per year. However, for severe illness, the incidence is identical for NPNL women and lead males. The majority of illness episodes were mild and were experienced by nearly all adults. Of the severe illness episodes, 52% were found in pregnant women, with lower but similar proportions in NPNL women and men, 35% and 37% respectively.

The types of adult illness were mainly infectious in nature; predominantly respiratory illness, fever (including clinical malaria) and diarrhea. There was also a high incidence of non-infectious illness such as musculoskeletal problems and subjective complaints of dizziness and headaches among all groups of adults. Episodes of epigastric pain and upper abdominal pain, particularly in men, were also relatively high, suggestive of ulcer symptoms.

Illness incidence is presented for women by reproductive status and for men in Table 3.2. Lactating women have a slightly higher total illness incidence than pregnant and NPNL women, which may reflect greater nutritional stress during lactation. Pregnant women have a comparable illness incidence to NPNL women. However, severe illness incidence is highest in the pregnant women (see Table 3.2).

TABLE 3.2.
Incidence rates of all illness in women by reproductive status (illness episodes per person-week and person-year) compared to illness in men

	n	No. weeks observed	Incidence Rate: Illness episodes per person-wk	person-yr
Pregnant women	174	34.9	0.288	15.0
Lactating women	156	15.7	0.328	17.1
NPNL	162	46.7	0.268	14.0
Men	247	85.1	0.153	8.0
Severe illness				
Pregnant	174	34.9	0.020	1.0
NPNL	262	46.7	0.012	0.6
Men	247	85.1	0.012	0.6

Prevalence

Period prevalence is defined as the number or proportion of days ill due to total or specific categories of morbidity, covering a specific time period in a specific population (2). Days ill or percent of time ill, per year are used here. Period prevalence gives a better picture than incidence of the time spent ill.

Children

Mean days ill per year and percent of observed days spent ill are presented by target individuals in Table 3.3. Male toddlers and male infants have a comparable prevalence, as do female toddlers and female infants. Female illness prevalence exceeds that of the males. Although illness incidence in toddlers is higher than in the infants, the longer illness duration in infants results in a higher illness prevalence. Prevalence in schoolers is less than half that of younger children.

TABLE 3.3
Mean days ill per year and mean percent of observation period study children spent ill

Cohorts	n	No. days observed	Days ill per year Mean ± SD		Percent of observed period spent ill Mean ± SD	
Male schoolers	74	380	67.9	65.2	18.7	17.9
Female schoolers	60	392	57.1	57.2	15.7	15.7
Male toddler	53	748	153.9	85.3	42.3	23.4
Female toddler	57	335	171.3	88.6	47.1	24.3
Male infant	76	172	153.9	82.8	42.3	22.7
Female infant	60	172	169.3	82.6	46.5	22.6

The percent of time spent being sick among the children is impressive. Infants and toddlers are sick about 45% of the year, and schoolers about 17% of the year. Of the time spent ill, 92.5% involved mild illness and 7.5% severe illness. Not only were girls sick more of the time than were boys, but a greater proportion of the girls' than the boys' illnesses were classified as severe.

Adults

Total illness prevalence in men is about half that in women (see Table 3.4). In pregnant women, illness prevalence was as high as 46% of all observed days. Overall, women in the CRSP sample spend just over 1% of all days severely ill per year, but pregnant women spend an average of 4.4% of their time severely ill.

The higher prevalence of total illness in pregnant women may reflect increased nutritional stress, a lower energy intake compared to NPNL women and altered immunity during pregnancy (3).

TABLE 3.4.
Mean percent of time spent ill in women by reproductive status and in men

Target Individual	n	No. days observed	% total days ill	% mild illness	% severe illness
All women	247	586	38	21.7	1.1
Pregnant women	174	244	46.0	40.0	4.4
Lactating women	156	110	25.3	24.2	1.1
Men	247	596	21.0	19.0	1.6

Seasonal Trends

The seasons in Embu are as follows: warm-dry, January through March; long rains, April through June; cool-dry, July through September; short rains and a warming trend, October through December. The drought occurred in late 1984 with an absence of the long rains in April and May and delayed and diminished short rains in October and November. A striking finding was that illness episodes doubled in 1984 compared to 1985 (see Figure 3.1), but otherwise there was no strong seasonal pattern for adult illness.

Seasonal trends are examined in children by percent of children ill by season (see Table 3.5). In general, a greater percentage of children were ill in 1984 than in 1985, concomitant with the severe drought and food shortage which occurred in 1984. However, the warm, dry season (January-March) of 1984 contained only a partial sample of children because enrollment of the groups was gradual over 3 to 4 months and no infants were yet "born into" the study. In addition, for the cool-dry season (July-September, 1985) and in the short rains (October-December 1985), many of the target children whom were studied in 1984 had completed the study and were no longer being observed. The resultant small sample sizes may have distorted the true morbidity picture in early 1984 and late 1985 (see Table 3.5).

TABLE 3.5.
Overall illness by season, 1984 and 1985

	1984				1985			
	Warm Dry	Long Rain	Cold Dry	Short Rain	Warm Dry	Long Rain	Cold Dry	Short Rain
Schoolers								
Male (1037)*	5.9	13.8	16.0	9.2	6.5	4.0	3.4	0.8
Female (831)	6.3	13.8	15.4	7.8	6.9	5.5	4.2	0.4
Toddlers								
Male (1115)	1.1	10.6	17.7	10.9	13.5	6.4	1.9	0.4
Female (1409)	1.9	14.3	17.7	10.9	11.8	6.3	2.1	0.1
Infants								
Male (497)	-	3.2	11.9	9.9	18.9	11.4	8.3	2.1
Female (590)	-	2.9	9.8	12.2	17.0	14.4	8.4	1.2
Total children (5740)	2.7	10.8	15.5	10.1	11.9	7.3	4.1	0.7

* Number of illness episodes in brackets

When individual types of illness are examined seasonally, lower respiratory infections among all children are most prevalent during cold seasons and in the long rains (see Figure 3.2). Of interest is that the long rain season were absent during the drought in 1984 and the rates for upper respiratory infection during the long rains were higher in 1985 than for those months in 1984. Diarrheal disease in infants and toddlers increased in the warm-dry and the long rainy season. Diarrhea in the schoolers was of very low prevalence throughout the year.

Fever tended to increase in the long rains and cold seasons in infants and toddlers. However, clinical malaria showed no increase during the rainy seasons but rather in the ensuing cold months. This may have been due to the filling up of stream beds and lakes which became breeding places for mosquitoes.

Eye infections were especially prevalent in the warm-dry and long rainy seasons. An increase in skin infections in the cold dry season of 1984 may have reflected less washing during the drought in 1984. Also at night the temperatures can approach freezing and many children and/or adults may sleep huddled together for warmth, thus increasing physical contact.

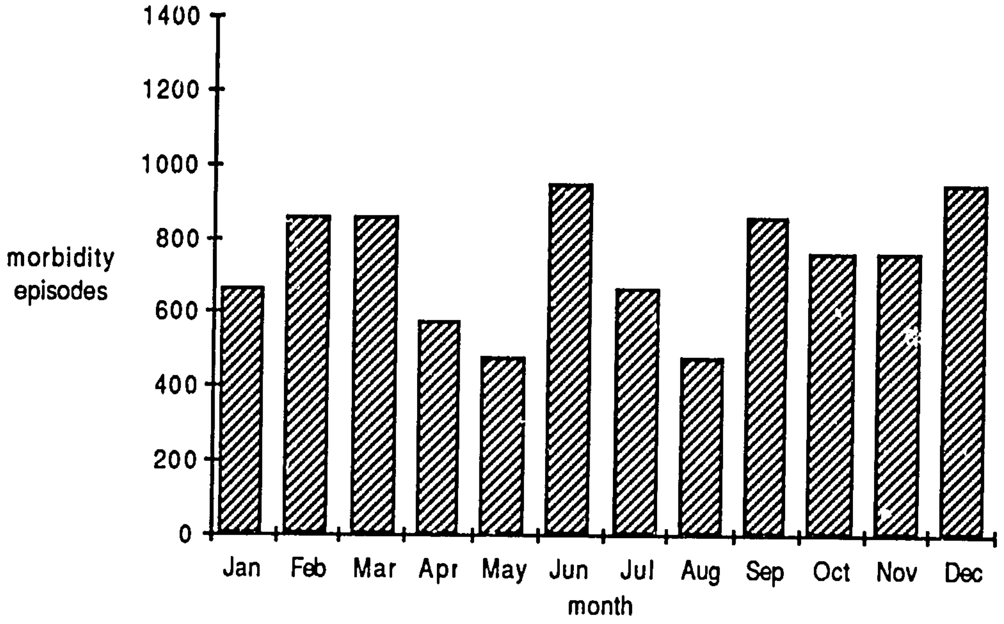

FIG 3.1a Number of morbidity episodes (all illnesses combined) in 1984 by month for all target individuals. (total number of episodes = 5085, number of individuals approximately = 875)

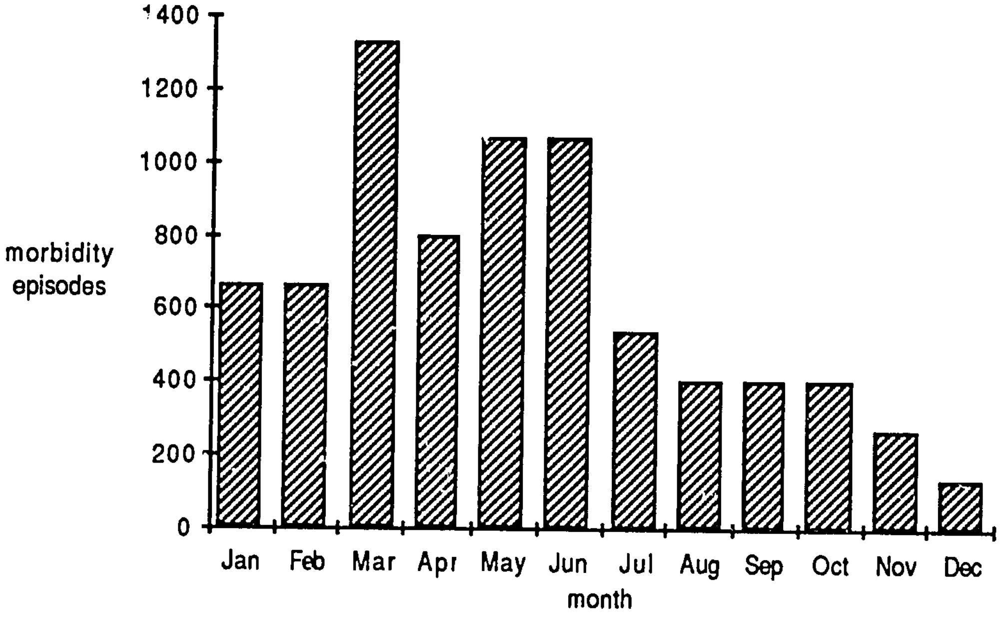

FIG 3.1b Number of morbidity episodes (all illnesses combined) in 1985 by month for all target individuals. (total number of episodes = 2128, number of individuals approximately = 600)[1]

1 Sample size decreased drastically during the last months of 1985 with this accounting for the low number of episodes in the last 6 months.

Proportionate Morbidity

Of the illnesses reported or observed, the most common conditions are acute respiratory disease, diarrhea, fever, and eye and skin infections in all age groups.

Children

Proportionate morbidity is presented for infants, toddlers, and schoolers in Table 3.6. Of all age groups, respiratory illness was the highest among the infants. Eye infections were the next most frequent, again in the infants and the toddlers. In the infants, the majority of eye diseases were conjunctivitis and two cases of gonococcal ophthalmitis were seen.

Among the study population diarrheal disease is not as prevalent as in more urban and populated areas of Kenya. This may be due to the fact that the people live in scattered compounds throughout the countryside. Also a comparison of reported diarrhea incidence versus a cross-sectional prevalence study in the CRSP sample by Thomas and Neumann (4) showed an under-reporting of diarrhea in the longitudinal study. Diarrheal disease was found to be highest in the toddlers who had already been weaned. The infants who are predominately breast fed have the lowest rates, next to the schoolers.

Febrile illness, with no other symptoms present, was seen most frequently in the toddlers and infants and least in schoolers. In all age groups a number of febrile episodes were probably diagnosed as clinical malaria.

Trauma begins to appear in the toddler and is much more prevalent in the schoolers. Fractures due mainly from falls from trees, burns and cuts comprised the bulk of the trauma.

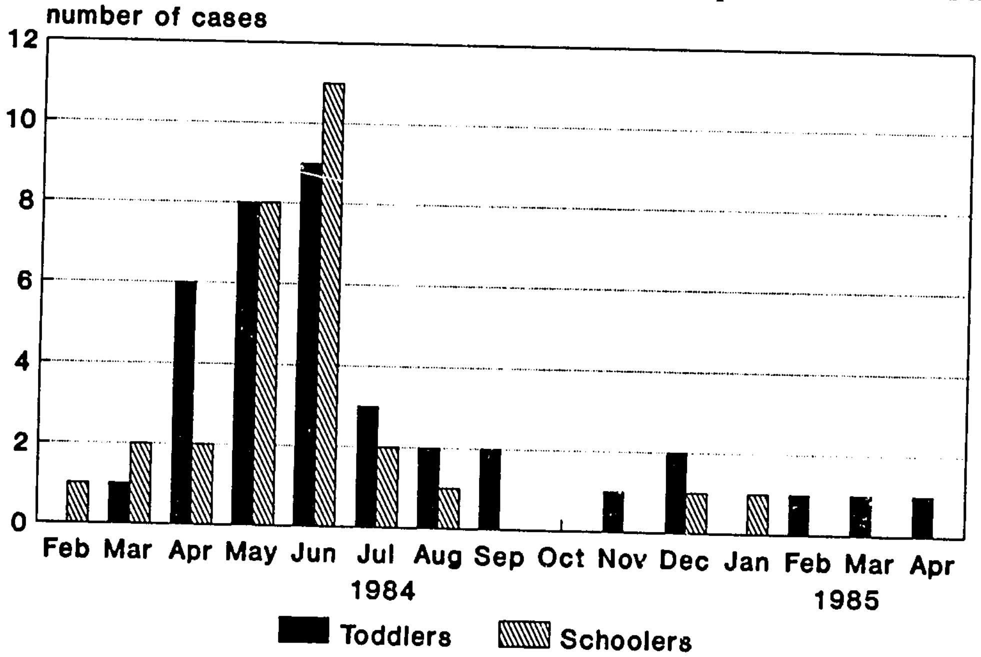

FIG 3.2. Time distribution of lower respiratory infections

TABLE 3.6.
Proportionate morbidity (new episodes for infant, toddlers and schoolers by sex--followed longitudinally for six months for infants, and twelve months for toddlers and schoolers)

	Infants		Toddlers		Schoolers	
	M	F	M	F	M	F
No. of episodes	473	350	657	858	551	446
No. of children	76	60	53	57	74	60
Person-mos.	435	343	588	635	935	781
Respiratory						
Upper	50.1	52.9	47.0	42.9	46.3	43.9
Lower	3.0	0.9	1.9	2.6	2.0	3.3
Otitis Media	1.3	0.0	0.2	1.6	0.2	0
Gastrointestinal						
Diarrhea	7.1	4.9	8.2	9.2	2.0	1.8
Symp. GI, abdominal pain, vomiting	1.3	2.0	4.3	4.8	12.3	10.9
Mouth, teeth, Gums	3.8	3.1	1.1	1.4	2.0	2.0
Febrile						
Fever*	4.2	3.1	6.7	3.8	2.2	2.7
Malaria (clinical)	1.5	2.0	0.2	3.7	9.3	5.6
Eye: conjunctivitis	22.1	26.6	18.0	20.2	9.3	13.5
Skin						
Infection	1.5	2.0	2.1	3.1	2.5	2.0
Dermatitis	2.6	1.4	3.3	2.6	1.8	2.5
Bones, joints						
Arthritis	0.0	0.0	0.0	0.0	0.2	0.9
Muscle, back pain	0.0	0.0	0.0	0.0	1.3	2.9
Genitourinary						
Urinary infection	0	0	0.2	0.2	0	0.2
Tuberculosis Pulmonary	0	0	0	0	0	0
Trauma	0.2	0.3	1.8	1.9	4.5	2.5
Functional symptoms						
Headache, dizziness	0	0	0.3	0.3	3.3	2.9

* Fever as predominant symptoms

Adults

In adults, the pattern of proportionate morbidity differed little from that of the children. The main differences were due to relatively high musculoskeletal and arthritic complaints, no doubt related to agriculture work. Psychologic and functional symptoms, such as headaches, dizziness and dental problems were also reported. A fairly high percent of upper abdominal complaints, i.e., epigastric pain, was found which points to the presence of ulcers (see Table 3.7). Anxiety and depression, based on one-time cross-sectional testing, were present in 12.7% of women and 3.7% of men. Of the men, about 35% were found to drink heavily, over 3 liters of beer per day, based on a cross-sectional set of interviews. Women rarely drank alcohol (see Kenya Project Final Report, 1987, for details of both studies).

Sexually transmitted disease is grossly under-reported judging from the high number of cases of pelvic inflammatory disease treated at the hospital and cases of gonococcal ophthalmitis in newborns. CRSP project blood samples collected between 1984 and 1986 were negative for HIV infections (5).

TABLE 3.7.
Proportionate morbidity (new episodes) for lead females* by reproductive status and lead males

	NPNL†	Pregnant	Lactating	Men
No. of episodes	1643	1097	801	2545
No. of individuals	262	174	156	247
Person - mos.	2845	1412	560	4888
Respiratory				
Upper	27.5	25.5	28.6	27.0
Lower	1.9	2.4	1.4	2.0
Otitis Media	0.7	1.5	0.0	3.6
Gastrointestinal				
Diarrhea	1.7	1.9	2.1	9.0
Symptomatic: heartburn, abdominal pain	7.6	9.5	6.1	4.8
Mouth, Dental				
Dental	1.4	0.7	1.5	1.0
Stomatitis	0.8	0.4	1.5	2.0
Febrile				
Fever	3.6	4.7	3.4	2.0
Clinical malaria	10.2	9.7	12.2	15.0
Eye				
Infection (including trachoma)	3.4	4.2	23 2.9	2.0
Skin				
Infection, dermatitis	1.6	1.7	9 1.1	3.0
Bone, joints				
Arthritis, muscle, joint, back pain	13.7	10.9	15.2	22.5
Genitourinary				
Urinary infection	0.8	1.6	0.8	1.0
Sexually Transmitted Disease*	0.3	0.2	0.2	9.0
Tuberculosis				
Pulmonary	0.1	0.2	0	<0.1
Trauma				
Soft tissue, fractures, head trauma	2.5	1.5	2.2	7.9

	NPNL†	Pregnant	Lactating	Men
Functional symptoms				
Headache, dizziness, emotional problems	6.9	7.4	7.1	6.7
Other	14.5	15.9	12.7	3.0

* n=247 women followed longitudinally for a mean period of 18 months
† non pregnant, non lactating

Mortality

Adults

Three of 247 men or 12 deaths per 1,000 occurred in the CRSP sample over the two-year period of study. Two men died of malignant hepatoma and one of laryngeal cancer. There were no deaths among the women studied. Hepatitis, cirrhosis and aflatoxin exposure, risk factors for hepatoma, are relatively common in Embu (6).

Perinatal Deaths

Five infant deaths all occurred under one week of age, due to low birth weight and in one infant the aftermath of breech presentation and C-section. This gives a perinatal death rate of 37 per 1,000 live births compared to a rate of about 10 per 1,000 live births in the USA. No infant, toddler, or schooler deaths occurred among target individuals. However, among non target siblings, one schooler died of cirrhosis of the liver after long-standing hepatitis, and one toddler and one infant died of probable diarrheal dehydration and pneumonia.

Gender Differences in Morbidity

Women have significantly higher morbidity incidence rates than men (as shown by the Mantel Haenszel Chi Square test, $\chi^2 = 24.4$ $p<.0000$). Even with the exclusion of pregnant and lactating women, the gender difference between male and female illness prevalence and incidence persists. These gender differences are seen for mild illness but not for severe illness. The fact that the lead females were more readily available for interview and illness observation than the men, and that a considerable proportion of the information on the men was derived from reports by their wives who may not have been aware of their husbands' mild illnesses may have been a factor. Also, the women may have reported a variety of minor complaints in order to receive symptomatic treatment from project health personnel, considered a positive project benefit by the study participants.

For school-age boys, there was a higher reporting of mild illness than for girls of the same age, yet girls were found to have more severe illness in this age group. Boys may be more

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favored by their parents with greater concern shown for their minor illnesses; thus illness reporting for boys may be more conscientious than for girls.

Better nourished and fed children had more, rather than less, mild illness reported, particularly in the toddlers and school boys. This was seen in families of better educated parents, who may have been better reporters of illness. In addition, better nourished children are more active and probably interact with a greater number of individuals, thereby increasing their illness exposure.

Changes in Food Intake, Activity and Functional Ability Due to Illness

Alterations in food intake, activity and task reallocation during illness in adults were measured semi-quantitatively to examine the impact of illness on food intake and daily living activities. These alterations also served as criteria for illness severity.

The scale used for describing changes in food intake, activity and for task reallocation and task assistance are presented in Table 3.8.

TABLE 3.8.
Semi-quantitative criteria to evaluate impact of illness on food intake, activity and task reallocation

Food Intake		Activity	
Scale		Scale	
0	Usual intake	0	Usual activity
1	Slight decrease in usual intake	1	Moderate reduction in activity
2	Liquids only	2	Bedridden
3	Water only	3	Critical
4	Nothing by mouth		

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Task Reallocation

Degree of assistance	**Tasks**
No help received	Salaried position
% help received	Animal, agricultural, other farm work
Task reassigned completely	Housekeeping, compound care
	Child care
	Procuring of food, food preparation
	Fetching water, fuel

The effects of illness on food intake and activity are presented by categories of common morbidity in all target individuals combined (Table 3.9). In descending order, the greatest reductions are seen with fever, digestive tract disease, and respiratory illnesses. A detailed analysis of acute illness impact on food intake in toddlers is included later in this chapter.

As for reduction in activity level, febrile episodes were associated with the greatest reduction in activity, followed by digestive tract illnesses, then respiratory illness, following the same pattern as for reductions in food intake. With mild illness, there was considerable reduction in activity, particularly with fever and digestive tract illness. The majority of people who were severely ill had limitation of activity with 6 to 15 % of the severely ill being bedridden.

TABLE 3.9.
Effect of illness on food intake and activity; all age groups combined*

	Food Intake			Activity		
Percent:	usual %	reduced %		usual %	reduced %	bedridden %
Respiratory			mild	85	15	<1
(all)†	80	19	severe	34	5	7
Fever (all)	50	50	mild	52	47	1
			severe	37	58	6
Digestive tract	40	40	mild	68	32	<1
(all)			severe	20	65	15

* Differences all significantly different by Chi Sq. Test, $p<.05$
† All = mild + severe

The proportion of time during illness in which activity is decreased or the person bedridden is shown in the women by reproductive status and in the men in Table 3.10. Because of the preponderance of mild illness, a greater percent of the time was spent inactive due to mild illness than to severe illness.

TABLE 3.10.
Percent of time per year that an adult has decreased activity or is bedridden

	Women				Men	
	Non pregnant		Pregnant			
	Activity decrease %	Bed-ridden %	Activity decrease %	Bed-ridden %	Activity decrease %	Bed-ridden %
Mild	8	0.3	11	0.4	4	0.2
Severe	1	0	1	0.2	1	0.2
All illness	9	0.3	13	0.5	4	0.3
Days/yr	33	1.0	47	2.0	15	1.0

Women had over twice the percent of illness days with decreased activity than did men (see Table 3.10), with pregnant women having a greater percent of inactive time than non-pregnant women. However, for non-pregnant women and men the percentage of time spent bedridden was similar. A slight increase was seen for pregnant women with severe illnesses.

For all illnesses, the relatively short time spent bedridden compared to the USA for similar illnesses was striking (7). It would appear that adults in Kenya cannot afford the luxury of being bedridden at the same level of morbidity as those in a country like the USA.

Task Reallocation

The degree to which adults were able to carry out their usual tasks of daily living when ill was assessed. The task categories are listed in Table 3.8.

Pregnant women required the most help with daily tasks during a given illness, and the tasks had to be completely reallocated to another family member in an about 20 to 25% of illnesses (see Table 3.11). Non-pregnant women and men were much more able to cope with their usual tasks during illness. Help was provided or the task reassigned, in descending order, to husbands, other adults in the household, friends, or school-aged children. The men were willing to carry out their wives' work. The most help and task reallocation were needed during febrile episodes, diarrhea, arthritis and emotional illness. Most people needed to reassign tasks mainly during severe illness episodes. The groups requiring or requesting the most assistance and task reallocation were, in descending order, pregnant women, males, and non pregnant women.

TABLE 3.11.
Percent of illness episodes (major categories combined) requiring help (HR) or task reassignment (TR), by type of daily activities: Presented by gender and pregnancy status (1985 sub-sample).

	Women				Men	
	Non pregnant		Pregnant			
Level of Help	HR	TR	HR	TR	HR	TR
Tasks:						
Salaried jobs	NA*	NA	NA	NA	1	2
Animal and agricultural work on own farm	5	1	18	9	19	6
Housekeeping and compound care	7	8	21	20	0.2	9
Child care	2	11	11	26	NA†	1
Food: procurement, preparation and cooking	8	6	17	24	NA†	1
Fetching fuel, water	8	4	27	8	NA†	1

* Very few women engaged in salaried employment.
† Men are usually not engaged in child care, employment, food preparation, fetching water, cooking, etc.

The tasks requiring the greatest amount of help and reassignment during illness were agricultural and farm work, for both pregnant women and men. This was the only task for which the men required assistance. For the pregnant woman, housekeeping and compound care, child care, food procurement and preparation, and fetching fuel and water required the most help or task reassignment to other household members (see Table 3.11).

DETERMINANTS OF MORBIDITY

In contrast to numerous research studies on the interaction of nutritional status and infection (8), relatively little research exists on the role of food intake per se, or mild/moderate malnutrition as a predictor of illness or infection. The ensuing analyses examine to what extent food intake, both quantity and quality, and other factors predict morbidity. The possibility exists within the CRSP data sets to examine the interactions of not only energy intake, but numerous nutrients in relation to morbidity. The many intervening variables related to morbidity, are also available for study.

Determinants of Illness in Men

Using bivariate analysis, statistically significant correlations between severe illness in men and intake of animal protein are seen. Illness among women and children living in the household, socioeconomic status of the family, poor household sanitation scores, and increasing age all contribute to severe illness.

TABLE 3.12.
Correlates of severe illness prevalence in men

	n	r*	p
Animal protein g/d	230	.14	.03
Age	228	.15	.02
SES	228	-.15	.03
Sanitation score	229	-.12	.08
Mild illness - wife	233	.19	.003
Severe illness - wife	143	.30	.0005

* Pearson's correlations 2-tailed, $p<.05$

A multiple regression analysis for severe illness in men shows that low SES and increasing age are the two strongest predictors of severe illness (see Table 3.13).

TABLE 3.13.
Multiple regression analysis for predictors of severe illness

	B-value	SE	F	p
Intercept	21.87			
Age	.46	.18	6.8	.01
SES	-.22	.08	6.9	.009

$R^2=.05$; $p<.003$, $n=227$

Determinants of Illness in Women.

Determinants of morbidity in women are analyzed by reproductive status, non-pregnant and pregnant, and using bivariate and multivariate analyses. Correlates of mild and severe illness are shown in Table 3.14.

TABLE 3.14.
Correlates of mild and severe illness in non pregnant and pregnant women

	Mild†				Severe†			
	Non pregnant		Pregnant		Non pregnant		Pregnant	
	r‡	p	r	p	r	p	r	p
Family illness†								
Husband	.16	*	.23	**			.43	***
Toddler	.28	**	.56	***			.29	***
Maternal age	.22	***	.21	**			.22	***
Household (HH) factors								
HH size	.26	**	.21	**			.21	*
No. child <6yr	.22	**						
SES							-.16	*
Sanitation	-.37	***	-.20	**	-.37	***	-.20	**
Food Intake (g/d)								
Kcal	-.16	*			-.23	**	-.27	**
Fat					-.20	**	-.33	**
Animal protein							-.29	*
Body Measurements								
Head Circumference			-.15	*	-.27	***		
Hemoglobin	-.23	**						

† Prevalence of mild and of severe illness
‡ Pearson's correlations: 2-tailed at significance levels:
* borderline, ** 0.1 to 0.5, *** <.009

Mild Illness

The factors associated with mild illness prevalence in pregnant and non-pregnant women are very similar and will be considered together here, although the analyses were carried out by reproductive status. It was shown earlier that pregnant women have significantly more severe illness than non pregnant women. One important difference in these two groups is that energy intake is much lower in pregnant women than the NPNL women. Also, the pregnant state imposes changes in the immune system and other physiological changes which may increase risk of infection (3).

The main correlates of mild illness are household characteristics and familial illness. An examination of food intake variables indicates that only energy intake has a borderline negative association with mild illness. The greater the number of people living in the household and especially the number of children under six years of age, the greater the illness prevalence in the women. Household sanitation score, rather than SES, predicts low-grade illness; the higher the score, the lower the low-grade illness prevalence (see Table 3.14).

For prevalence of mild illness in pregnant women the variables which enter the model are the following: mild illness prevalence in their husband and in their toddler and the mother's own head circumference. The latter correlates strongly with her height and is an indicator of long term nutritional experience (see Table 3.15). Together the variables explain 40% of the variance in mild illness. In non-pregnant women only the husband's illness prevalence entered the regression.

TABLE 3.15.
Stepwise multiple regression of morbidity prevalence in pregnant women (mild illness)
Dependent variable: prevalence of mild illness in pregnant women

Variables entered	R^2 (increase)	F	p
Total toddler mild illness	.32	36.4	.0001
Mild illness in spouse	.36	4.8	.03
Head circumference*	.40	4.9	.03

* Head circumference enters equation in place of height

Severe Illness

The factors associated with severe illness are similar in non-pregnant and pregnant women, but nutritional factors play a more important role in pregnancy than other factors. Total energy and fat intake and long-term nutritional status, expressed by head circumference, are negatively associated with severe illness prevalence. The better the diet quality (i.e., animal protein and fat intake), the less severe illness is seen. For non-pregnant women, the main determinants of severe illness are the household sanitation score and food intake, both protective against severe illness.

For pregnant women additional strong predictors of severe illness are mild illness in the husband and toddler, increasing maternal age, and household size. Low SES relates only weakly to illness prevalence.

In summary, the household exposure to sick members, the household composition, and increasing maternal age are positively associated with total illness prevalence in women. Food intake, particularly of total energy, fat and animal protein, is "protective" against severe illness in non pregnant and in pregnant women. The low food intake of pregnant women place them at greater risk for severe illness than in non pregnant women. A consistent finding is that good household sanitation is "protective" against all illness.

Determinants of Toddler Illness

Mild Illness

There are many statistically significant associations between toddler food intake and morbidity. Mild illness correlates positively with kcal intake and animal protein from 18 to 21 months but negatively with food intake variables thereafter. In the younger toddlers, the better they are fed, the higher is the prevalence of mild illness. One explanation is that the better fed child is more active and interactive with the environment and is exposed to more people than a poorly fed child. Another possibility, not analyzed as yet, is that partial breast feeding in the 18 to 21 month old toddler (25% of toddlers received some breast milk and thus less food until 20-21 months) may be somewhat protective against illness. Maternal low grade illness, poor household sanitation, and low maternal literacy are also associated with mild illness in the child (see Table 3.16).

TABLE 3.16.
Factors associated with mild and severe illness in toddlers (n=11-120)

	Illness		Duration	
	Mild	Severe	Fever	Respiratory
	r*	r	r	r
Nutrients				
Kcal/d (18-21 mos)	.25	-.21	-.21	
Total protein g/d	.19	-.18	-.17	
Fat g/d	NS	-.18		
Carbohydrate g/d	.23	-.19	-.17	
Sanitation score	-.21	-.18	-.15	
Paternal Literacy	-.19			
Maternal Literacy				-.20
Maternal illness mild	.43			.63

* Pearson's correlation 2-tailed, p<.05 to .001 for all correlations shown.

Multiple regression analyses for mild illness

Because the younger toddler has been weaned more recently than the older toddler, the sample is examined in two age groups: 18 to 24 months and 24 to 30 months.

The best combination of variables that predicts mild illness in the toddler at 18 to 24 months is household sanitation and maternal fat intake. The household sanitation score alone accounts for 40% of the variance in low grade illness for the toddler (see Table 3.17). A well-nourished mother is better able to care for her household and children in terms of cleanliness.

The child's illness status at 18 months, maternal low grade illness and food intake are important factors in predicting mild illness between 24 and 30 months. Animal protein intake preceding the illness is protective against low grade illness in this age group. In combination, the maternal illness, the child's food intake prior to the period of illness accounts for 43% of the variation in mild illness prevalence (see Table 3.17). A mother, if unwell and if she is pregnant also (as shown above) she may not be able to care for her household or children as well as a healthy mother.

TABLE 3.17.
Multiple regression analysis for predictors of mild illness in toddlers from 18 to 30 months.

Mild Illness 18 to 24 mos (n=84)			Mild Illness 24 to 30 mos (n=80)		
Variables	Std Reg coeff	p	**Variables**	Std Reg coeff	p
HH sanitation score	-.20	.0001	Child mild illness, 18 mos.	.33	.002
Maternal fat intake	-.50	.005	Maternal mild illness	.33	.002
			Animal protein intake 18-24 mos.	-.23	.03
			Sex (1=M, 2=F)	.15	.10
R^2 = .40, F= 3.39, p < .0001			R^2 =.43, F =9.6, p =.0000		

Severe Illness

Food intake plays an important protective role in severe illness, especially in relation to febrile episodes in the toddler. The better the child's intake of total energy, protein, fat and carbohydrate in the preceding months, the less severe illness is experienced by the child. Also the greater the intake of the above nutrients, the shorter the duration of the febrile illness. Although lagged analyses suggest that food intake shortens illness duration, the presence of fever may decrease concurrent food intake.

Parental factors are also important. The duration of respiratory and diarrheal disease in the toddler is positively associated with maternal mild illness, which may diminish the mother's ability to care for her ill child. Maternal literacy is important in shortening illness duration which may reflect better care for the child as well as seeking health care. The higher the literacy, the shorter is duration of respiratory illness (see Table 3.16). Also, literate parents may be more knowledgeable about caring for their sick children and seeking more medical care than less literate parents.

Multiple Regression Predicting Severe Illness in Toddlers

Seasonality and energy intake predict severe illness in the 18 to 24 month old toddler. Also, the less the child weighs at 18 months, the more illness it experiences in the ensuing period. Seasonality refers to the birth date and age of the child in relation to the food shortage. The younger the child during the shortage period, the less illness experienced subsequently.

In examining the combination of factors predicting severe illness at 24 to 30 months, a child's severe illness at 18 months predicts severe illness at age 30 months. Short stature at 18 months has a negative effect. The same conditions accounting for severe illness at 18 months are still present (see Table 3.18). In the analyses of lower respiratory infection, discussed in the last section, shorter children also are at greater risk for lower respiratory infection.

TABLE 3.18.
Multiple regression analyses to predict severe illness in toddlers aged 18 to 24 months and 24 to 30 months.

Severe Illness 18 to 24 mos (n=84)			Severe Illness 24 to 30 mos (n=82)		
Variables	Std Reg coeff	p	**Variables**	Std Reg coeff	p
Season	-.32	.001	Severe illness at 18 mos	.24	.03
Kcal/kg 18-24 mos	-.17	.11	Length at 18 mos	-.18	.09
Weight at 18 mos	-.22	.04			
$R^2 = .17$, $F = 5.6$, $p < .002$			$R^2 = .09$, $F = 4.1$, $p < .02$		

Attempts to identify the determinants of illness are highly relevant to intervention programs. Improving food intake, both diet quality and quantity, and the child's growth; and reduction of general household illness through improved sanitation and increased parental literacy are important directions to pursue.

In larger households with many young children, less child care and food per capita are available, predisposing family members to more illness. The strong linkage between sanitation and mild illness is readily understandable. Many of the mild illness, such as skin and eye infections and mild diarrhea are reflections of unsanitary conditions. The food intake and health of the mother and literacy of the parents emerge as important links to household sanitation and care of the child. Pregnancy, as was shown in the discussion of task reallocation, also diminishes the ability of a sick mother to care for her household and children.

IMPACT OF ACUTE MORBIDITY ON FOOD INTAKE IN RURAL KENYAN TODDLERS

The synergism between nutrition and infection in young children in less technically developed countries is well appreciated (8). Infections not only produce catabolic effects and malabsorption, but may induce anorexia resulting in reduced food intake (9). Moreover, imposed dietary restrictions during illness may further contribute to malnutrition. Because of the high incidence and prevalence of a variety of mild and severe infections; predominantly respiratory, gastrointestinal and febrile illness; a significant negative impact of these on a child's food intake might be expected.

It was possible to quantify the impact of common acute morbidity on food intake in a group of 110 toddlers in the CRSP study. The weekly documentation of morbidity in children living at home and their quantitatively measured food intake on days with and without illness and in the convalescent period make it possible to determine the effect of morbidity on food intake in the toddlers. The withholding of food is not a common practice among the study population.

Procedures

The actual analytic sample for this analysis is represented by nearly all of the toddlers in the entire sample, numbering 110 (of 120) with 57 boys and 53 girls. Children with chronic physical handicaps or retardation were not included. The total number of illness episodes which coincided with days of quantitatively measured food intake is compared to the total number of illness episodes or days ill with and without concomitant days of measured food intake. The sample encompasses 62% of mild and severe illness episodes and 84% of wellness episodes.

All toddlers were followed for at least a one-year period, from 18 to 30 months. If two episodes of illness (mild or severe) were reported on the same day, a single illness day was counted. If a mild and severe illness occurred simultaneously on the same day, only the severe illness was counted for that day. Wellness periods were defined as the periods in which no illness was reported. The child had to have at least two consecutive illness-free days to be counted as well. In this way, each day during the observation period could be designated as either a well day or an ill day.

Statistical Methods

Paired analyses with a general linear model (GLM) correction for unequal sample size are used. The repeated measures over time for each subject were averaged to obtain an estimate of the subject's average intake for each type of illness and wellness episode. Weighted means and SD were then computed across subjects for each gender group to obtain least squares estimates of the true group means. Tests of statistical significance between mean food intakes for each illness state (compared to wellness) were then computed using a GLM program with a categorical fixed effect for each illness type and a random effect for each child, which removes the within-child variation in intake to allow comparable estimates of the illness and wellness food intakes (10).

Findings

Nutritional Picture of the Overall Sample of Children

The overall weighted mean daily intakes for the study sample, averaged over the 18th to 30th month, were 868 ± 874 for boys and 840 ± 1033 kcal for girls, about 78% of the WHO/FAO/UNU recommended daily allowance. The diet is more fully described in Chapter Two. The children were stunted (5th percentile) and underweight (10th percentile) using NCHS reference levels for length/age and weight/age respectively. Z-scores for boys' and girls' length were $\leq$-2.0. See Chapter Five for more details on toddler growth.

Illness Picture

The leading causes of morbidity in this group of children, have been described earlier in this chapter (see Tables 3.6 and 3.7). Most illnesses were mild.

Mean Food Intake on Days of Wellness and Illness

Mean energy intake on days of wellness and on days of illness, for mild vs severe illness, are presented in Table 3.19. Statistically significant differences in mean daily kcal intake are seen between wellness vs. total severe illness, and mild vs. severe illness. Small differences between mild illness and wellness intake are present but not of statistical significance.

TABLE 3.19.
Food intake (kcal/day) during wellness, mild illness and severe illness episodes (weighted averages for kcal/day)

	Both Sexes				Males				Females			
	n1*	n2†	Mean±SD		n1	n2	Mean±SD		n1	n2	Mean±SD	
Wellness	110	1572	855	713	53	795	866	687	57	777	844	740
Illness												
Mild	102	1161	848	830	47	512	883	797	55	649	819	852
Severe	33	93	612	449	12	28	646	415	21	65	597	474

* n1 = number of toddlers
† n2 = number of observations

The differences between wellness and severe illness intakes and between mild and severe illness intakes are statistically significant, using t-tests ($p < .002$ -.001).

The girls fared worse than the boys, not only experiencing more severe illness episodes, but having a greater decrease in intake. Also, even when well, mean daily energy intake is less in girls compared to boys.

Changes in food intake were examined by specific illness categories in order to see which categories imposed a relatively greater decrease in kcal than others. Using paired analyses, person-averaged daily kcal intake per illness category was compared to each person's own mean wellness intake (see Table 3.20). Negligible or no decrements in energy intake were seen with eye, skin, or upper respiratory infections, low grade febrile illnesses (<101°F), or stomatitis.

Illnesses that were consistently accompanied by large, statistically significant decreases in food intake were symptomatic gastrointestinal (GI) complaints such as abdominal pain, lower respiratory infection, measles, febrile illnesses (>101 F), and clinical malaria.

TABLE 3.20.
Average differences in total daily kcal intake (wellness minus illness intake) for selected diagnostic categories (paired analyses)

	Males				Females			
	Intake decrement				Intake decrement			
Illness	n	Mean ±	SD	p†	n	Mean ±	SD	p
Upper respiratory	43	27	315		51	62	237	*
Lower respiratory	0	-	-		4	520	167	***
Otitis Media	0	-	-		3	136	463	*
Fever >101 F	7	132	311	**	5	52	332	
Clinical malaria	5	243	319		4	264	401	
Measles	0	-	-		3	232	440	
Stomatitis	1	82	-		3	34	396	
Upper GI	3	224	281	**	8	142	262	*
Abdominal pain	2	223	11	**	4	327	239	*
Diarrhea	10	141	614		12	243	317	**
Urinary tract		-	-			210	-	

† *<.07-.05; **<.05-.01; ***<.001

Food Intake during the Prodromal Period and Convalescent Periods

There was no appreciable difference seen between the prodromal mean kcal intake within one week prior to illness and wellness intake. This was true for both boys and girls.

To determine whether decreased energy intake during illness episodes was compensated for by greater than "usual" intakes in the first two weeks of the convalescent period, comparisons were made between mean daily convalescence intake and wellness intake separately for boys and girls. These analyses are cross-sectional, since food intake data on any one individual during the illness and convalescent periods was not frequent enough to permit a paired, within child analysis. Thus, some of the variation may be due to seasonal fluctuations in intake and individual child differences.

With regard to severe illness, two assumptions were made: that food intake was constant over the entire period of the illness, and that intake was constant over the first 7 days of the convalescent period. Actually no statistically significant variation in consumption over the first week of an illness episode or during the first week in convalescence was found.

convalescent period. Actually no statistically significant variation in consumption over the first week of an illness episode or during the first week in convalescence was found.

For mild illness, there was no compensatory increase in intake during convalescence compared to illness or wellness intake (see Table 3.21 and Figure 3.3). Given the great frequency of these illnesses, the energy loss could be considerable.

For boys recovering from severe illness, during the first week of convalescence the daily energy intake increased above wellness intake by 30 kcal/d and in the second week by 151 kcal/d, returning to the usual mean wellness intake at the end of the second post- illness week. The convalescent boys ingested only 36% of the energy that was lost per day of illness (see Table 3.21 and Figure 3.3). Given that the mean duration of a severe illness is 14.5 days, the boy forgoes a mean of 3190 kcal per severe illness.[1] At the level of an extra 30 kcal/d in week one and 151 kcal in week two of convalescence, at the end of 2 weeks of convalescence the child has a mean deficit of 1923 kcal/d due to the severe illness (assuming, unrealistically, that no other illness intervened). An additional 200 kcal/d for about two weeks would be required for recovery of the kcals lost to a severe illness.

Following a severe illness episode in girls, more striking changes are seen (see Table 3.21 and Figure 3.3). For the first week in convalescence girls ingest an extra 360 kcal/d above wellness levels. Given that the mean duration of severe illness in girls is double that of the boys (31.0 days vs 14.5 days), the mean loss per severe illness is 7435 kcal[2] despite the sizeable compensatory intake. As the girls intake returned to usual wellness levels by the end of one week, they still have a deficit of 4915 kcal per severe illness at the end of convalescence. The girls would need an additional 200 kcal/d for 4 to 6 weeks to fully regain kcals lost to a severe illness.

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[1] Mean decrease in severe illness is 220 kcal/d * 14.5 days duration (see Table 3.22).

[2] Mean decrease in severe illness is 247 kcal/d x 30.1 d mean duration (see Table 3.21).

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TABLE 3.21.
Energy intake during convalescence from mild and severe illness: measured in first week and during remainder of convalescence (weighted means)

	Boys				Girls			
	n1	n2	Mean ± SD		n1	n2	Mean ± SD	
Mild Illness								
First week	42	83	848	321	48	94	751	332
Remainder	53	274	868	461	54	239	874	500
Severe Illness								
First week	8	8	795	371	3	5	1220	472
Remainder	7	15	1017	299	10	20	883	233

n1 = number of individuals
n2 = number of observations

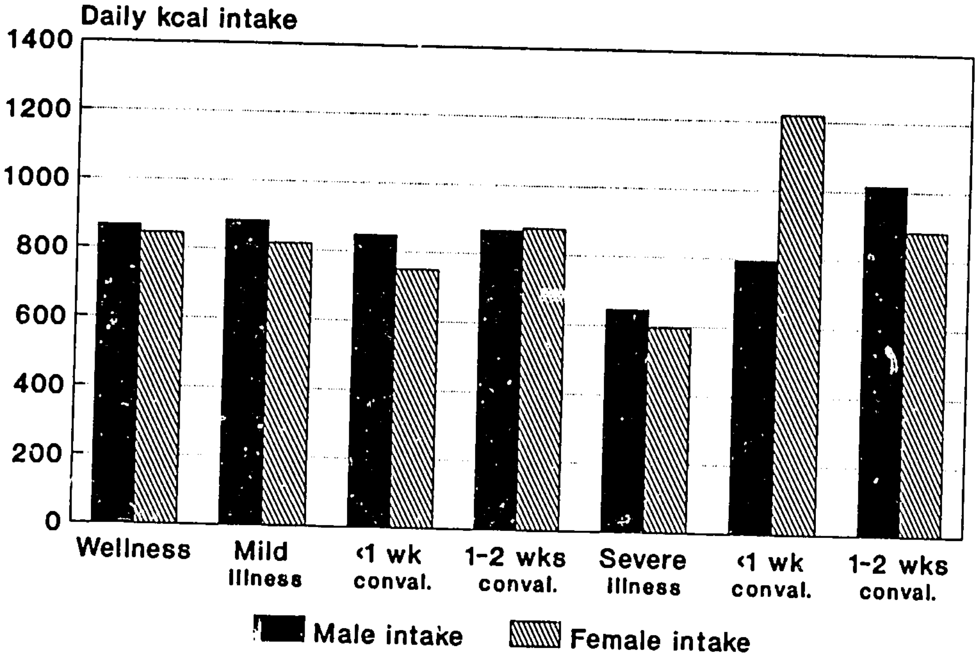

FIG 3.3 Average daily kilocalorie intake for toddlers for wellness, illness and convalescent periods.

Comment

Consistently large daily food intake deficits were seen for common lower respiratory infections; upper GI tract symptoms, such as vomiting with abdominal pain; fever; diarrhea and measles. Had the sample size of illness days with concurrent food intake measurement been larger and the food intake variance smaller, perhaps a greater number of significant differences in intake between illness and wellness would have emerged.

During the convalescent phase for severe illness, particularly in girls, there is an increase seen in intake which exceeds the wellness intake. However, a decline to wellness levels follows after one week. When comparing the illness deficit to the compensatory increase in intake in the convalescent period, there is still not sufficient additional energy intake to compensate for the loss of intake during the serious illness. Thus, the cumulative effect is a net loss of energy. Boys and girls experience about two severe illness episodes per year and illness related food intake deficits and the negative impact on growth could be considerable.

Concerning male/female differences, the girls have a larger energy deficit with severe illness than the boys (4915 vs. 1923 kcal) and the duration of severe illness is double that of boys. The larger compensatory convalescent food intake in girls probably reflects the greater illness-associated deficit and the attempt at recovery, once appetite has recovered and food is accessible.

Clearly an important mechanism for the adverse effects of infection on nutritional status is mediated, in considerable part, through a sizeable decrease in food intake associated with common infectious disease episodes. Thus, the compensatory feeding of sick children, for more than two weeks during the convalescent phase, is extremely important and eating must be actively encouraged.

MALNUTRITION AND LOWER RESPIRATORY INFECTIONS IN KENYAN CHILDREN

Respiratory infection is the leading cause of morbidity in Embu for both adults and children. Individual and family associated risk factors for lower respiratory tract infections in Embu toddlers were investigated during the Kenya Nutrition CRSP. The risk factors investigated in this analysis were nutritional status, household crowding, socioeconomic level, and paternal literacy.

Acute respiratory infections are one of the major causes of morbidity and mortality in children from developing countries (11). Severe malnutrition is known to be a risk factor for acute lower respiratory tract infections (ALRI) in children. It has not been established, however, that children with mild to moderate malnutrition are also at higher risk. Low socioeconomic status and crowded living conditions are more consistently found to be associated with ALRI.

The focus of the ensuing analyses were to determine if mild/moderate malnutrition affects the incidence of childhood lower respiratory tract infections among the rural Embu children. They also examine whether family size and crowded living conditions, low levels of maternal education, and/or literacy of mothers and family socioeconomic status are risk factors associated with the incidence of ALRI in children.

Nutritional status was determined by averaging the first two monthly measurements (at mos. 18 and 19) of weight and height, and calculating the percent of median weight-for-age (WAM) and height-for-age (HAM) based on the NCHS reference values (12). The definition of ALRI included clinical pneumonia, bronchiolitis, and bronchitis with increased respiratory rate >40/min, cough, ± fever, and retractions.

Crowding was defined in two ways: as the number of siblings under 16 years and as the number of persons sharing the same bed as the child. Smoking was not measured. Although most mothers in the community did not smoke, no estimate is available for the men.

Epidemiologic Analyses

Epidemiological analyses were conducted to estimate the strength of causal relationships between several exposures and the risk of developing a lower respiratory tract infection. The hypothesis tested is that pre-existing malnutrition (underweight or stunting) can predispose a young child to ALRI for a period of at least 5-6 months after documentation of the malnutrition.

The use of a multivariate Cox proportional hazards model enabled examination of the effect when changes in nutritional status over five-month periods were considered. Time-dependent nutritional variables were used which permitted reclassification of nutritional status over the study period. This was felt to be more biologically correct than relying on a single limited measure of nutritional states. Categorical analyses were performed using dichotomous cutpoints for reading and crowding and trichotomous cutpoints for nutritional variables. Modeling of continuous variables of the major exposures was also performed. Exposure was defined as percent of median for height and weight, number of siblings, and parental literacy. The reported results are rate ratios, 95% confidence intervals (CI) and p values derived from the hazards models controlling for SES.

The study population for the current analysis consists of 109 toddler-aged children (18-24 months) who were disease-free at the beginning of the follow-up. The group was followed up to one year or until the first occurrence of a lower respiratory infection. The crude incidence rate for ALRI was 0.096 per 100 person-days or 0.35 per year. For boys, it was 0.076 and for girls 0.109 per 100 person-days or 0.27 and 0.40 per year respectively. There were nineteen cases of ALRI among subjects who were followed for more than two months.

Results

Children who were underweight or short for their age, across a range of dichotomous cutpoints had a higher incidence of ALRI (see Table 3.22). For underweight children, rate ratios ranged between 2-3, with lower confidence limits close to or slightly exceeding 1. Using the cutpoint of weight/age <82% median, the adjusted rate ratio (RR) was 2.92, with a 95% confidence interval (CI) of 1.12-7.63. The effect of stunting on ALRI was similar. At the cutpoint of height for age <92% median, the adjusted rate ratio was 2.98 (1.06-8.34). No effect was seen with weight-for-height.

When two levels of malnutrition were compared to normal, the effect of moderate to severe malnutrition was stronger than of mild, especially for height. For those whose height/age percent of median was <90 (moderate to severe stunting), the RR for ALRI was 4.5 versus 1.0 for those with mild stunting at 90-95% of the standard. In contrast, moderate to severe underweight did not greatly increase risk of ALRI, when compared to normal weights/age (see Table 3.22).

TABLE 3.22.
Association between ALRI and malnutrition: hazard rates and 95% confidence limits

Exposure	Exposed Cases	Unexposed Cases	Hazard Ratio	Lower Limit	Upper Limit
WAM <81 vs ≥81	9	10	2.48	0.96	6.46
WAM <82 vs ≥82	12	12	2.92	1.12	7.63
HAM <91 vs ≥91	12	7	2.69	1.05	6.90
HAM <92 vs ≥92	13	6	2.98	1.06	8.34

Incidence of ALRI was also compared to parental literacy. On average, subject fathers' reading level was the equivalent of 5.5 years of schooling, whereas subject mothers' level averaged 3.5 years. Results of the categorical analysis are shown in Table 3.23. There was a strong and consistent increase in incidence of ALRI for subjects whose mothers' reading ability was low. If a mother's reading level was less than four years, the adjusted rate ratio was 4.9 (1.4-17.08). Correspondingly, fathers with a reading level of less than six years had more children with ALRI (adjusted RR=4.06 with 95% CI of 1.16-14.15). The effect increased as the cutpoint rose. The positive association of low parental literacy and ALRI was not confounded by nutritional status, nor was literacy a confounder for the association of malnutrition with ALRI association in this study.

TABLE 3.23.
Association between ALRI and parental reading: hazard rates and 95% confidence limits

Exposure	Exposed Cases	Unexposed Cases	Hazard Ratio	Lower Limit	Upper Limit
Maternal reading level					
<3 yrs. vs ≥ 3	15	4	4.34	1.41	13.34
<4 yrs. vs ≥ 4	16	3	4.90	1.40	17.08
Paternal reading level					
<5 yrs. vs ≥5	12	5	2.73	0.95	7.80
<6 yrs. vs ≥6	14	3	4.06	1.16	14.15

Household crowding was not generally found to be strongly associated with increased incidence of ALRI when the number of persons sharing the bed or siblings less than 16 years of age were used to define crowding (see Table 3.24). However, rate ratios for the various categories of crowding were consistently greater than one, and significant for children who had more than five siblings.

TABLE 3.24.
Association between ALRI and household crowding: hazard rates and 95% confidence limits

Measure of Crowding	Rate ratio (95% CI)	Lower limit	Upper limit	p
no. siblings < 16yr				
> 4 v. ≤ 4	1.93	0.75	4.97	.42
> 5 v. ≤ 5	3.21	1.21	8.49	.02
no. children sharing beds				
> 3 v. ≤ 3	1.50	0.58	3.87	.40
> 5 v. ≤ 5	1.42	0.41	4.96	.58

Conclusions

The data from this study support the hypothesis that pre-existing mild to moderate malnutrition and low literacy of both parents in a community-based population increases the risk of lower respiratory tract infections in children. An important limitation of the current study is the small sample size of ALRI and the low power resulting in wide confidence intervals around the measures of effect.

Nonetheless these data suggest that reduction of lower respiratory infections may be one of the benefits of improving the nutritional status of children. Long-term control includes overall improvement of socioeconomic conditions and attainment of higher levels of parental literacy. Other control measures might include teaching parents to recognize the signs and symptoms of serious respiratory infections in order to seek early treatment against a leading cause of mortality among young children in Kenya.

SUMMARY OF MORBIDITY STUDIES

The morbidity pattern in the Kenya CRSP sample shows a high burden of mild recurring illness in all age groups, but particularly in toddlers and pregnant and lactating women. Acute upper respiratory infections are the leading cause of morbidity. The infant group surprisingly has nearly as high an illness rate as the toddlers with regard to acute respiratory infections, fever and eye infection. Diarrheal disease rates were very low in all groups and severe illness is relatively uncommon.

Not only is the morbidity data set of intrinsic value and interest, but it is of broader interest to health planners. There are relatively few longitudinal community based studies of illness that have a household focus and include the major age groups in each household.

Seasonal trends were not striking, but quite definite for respiratory illness, eye infection and less so for diarrheal disease. Infants, however, appear to have less of a seasonal pattern of illness. The rate of respiratory infections is highest in the cold-dry period and the long rains, also a cool time of year. Close contact with families in crowded houses necessitated by rain and cold weather at night enhances the spread of infection. Eye infections were more common in the dry dusty seasons and during the long rains. The most noticeable seasonal pattern seen was with a doubling of morbidity rates during the drought related food shortage period in 1984, compared to 1985.

Functional effects of illness were seen in food intake and activity changes, particularly for febrile illness and severe illness. Pregnant women's activity was the most adversely affected by illness, often requiring a woman to obtain help or reassign her household work to others. The low energy intake during pregnancy no doubt is a factor here.

In examining the determinants of illness in all groups, several consistent trends emerge. Pregnant and lactating women have more mild illness, and pregnant women the highest (albeit low) severe illness rates. For mild illness household sanitation is the strongest predictor. This is not surprising when one considers that eye infections and gastrointestinal complaints compose much of mild illness. These are closely related to poor personal and household cleanliness and lack of safe water. Illness in other family members, be it mothers or toddlers is a strong determinant of mild illness due to exposure and a shared environment. Food intake appears to play only a small role in mild illness. For some groups of children, in fact, the better fed they are the more illness they have, presumably because they are more active and interact more with others. The mother's diet is also a factor in the child's illness duration, as is parental literacy. Child care and earlier use of community health facilities may shorten the child's illness duration.

Food intake, both quantity and quality, (particularly animal protein and fat intake) are strongly associated with low illness prevalence using lagged analyses. Food intake is a significant predictor of severe illness both in children and adults.

Acute illness was found to significantly reduce food intake in toddlers for common illnesses, particularly lower respiratory infection, measles, diarrhea and heartburn, epigastric pain and abdominal pain. During convalescence from severe illness it was shown that children who had sizable illness-related depression of food intake, increased their intakes above wellness levels during the first two weeks of convalescence. Their intakes returned to wellness levels after two weeks. Despite sizable daily increases, about 150 kcal in boys and 360 kcal in girls, they never totally regain the energy deficit. The remaining deficit per severe illness was found to be roughly 1000 to 3000 kcal, the larger deficit in girls. Given even one or two severe illnesses per year, plus many mild illnesses with smaller deficits, the cumulative effect no doubt results in poor growth.

Lastly, an epidemiologic analyses of nutritional and other risk factors for acute lower respiratory infection (ALRI) was carried out. ALRI is a leading killer of children not only in Kenya, but in many less technically developed countries. The findings show that low stature and to a lesser extent low weight for age place toddlers at increased risk for ALRI. Also parental literacy reduced the child's risk, and crowding (over five siblings in the household) increased the risk for ALRI.

Adverse effects of morbidity were also seen on pregnancy weight gain, on cognitive development in toddlers and school performance and cognitive function in children even when controlling for food intake and parental and home variables.

Thus, morbidity interacts with food intake as an outcome; as an independent variable in predicting illness and cognitive performance, and as an intervening variable as in pregnancy weight gain and in growth.

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CHAPTER FOUR.
REPRODUCTIVE FUNCTION

Examination of the research question: "Does maternal intake during pregnancy and lactation influence the course and outcome of pregnancy, the infant's endowment at birth and her/his growth during the first six months of life" was initiated in the first phase of the Kenya CRSP (Final Report, 1987) with analyses continuing into the second phase. A number of important findings emerged from the Kenya project which are strengthened and elaborated upon in this report. The earlier findings concerned the effect of food intake and other variables on pregnancy weight gain, birth weight and gestational age. Possible adaptations to and consequences of low maternal energy intake during pregnancy were also considered. A preliminary examination of the growth of the newborn during the first six months of life was regarded as an indicator of lactation function, and the role of infant morbidity and supplemental feeding were explored. This chapter reviews these earlier findings and reports the results of the more recent analyses.

REVIEW OF MATERNAL FOOD INTAKE, PREGNANCY WEIGHT GAIN AND BIRTH WEIGHT

Food Intake and Pregnancy Weight Gain

Energy intake, particularly fat and protein, prior to and during pregnancy, were found to relate positively and significantly to pregnancy weight gain (PWG). Kcal intake in the pre-pregnancy period and in all three trimesters of pregnancy, protein intake in trimester one and fat intake in trimester three all showed positive and statistically significant correlations with PWG [$r=.30$ to $.39$, $p<.01$-$.005$ ($n=139$)].

The Embu women progressively lower their food intake in the course of pregnancy, not only during the drought-associated food shortage, but in a normal year. The resulting mean PWG is 6.3 ± 3.4 ($\bar{x} \pm SD$) kg, half of the recommended weight gain for well-nourished women in the United States or the UK (1). The Embu women still manage to give birth to infants with a mean birth weight of 3.1 ± 0.5 kg. Ten percent of the infants are low birth weight (LBW), the majority of whom are intrauterine growth retarded (IUGR)[1]. Severe maternal illness including clinical malaria was found to have a negative effect on pregnancy weight and fat gain, particularly in the second trimester.

Using multiple regression analysis, in descending order of influence, fat intake in trimester 3 and gain in body fat between trimesters 2 and 3 had a positive influence, and total severe illness episodes, a negative influence, on PWG (see Table 4.1).

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[1] IUGR: 10th percentile of USA birth weights for gestational age (2).

TABLE 4.1.
Multiple regression for pregnancy weight gain.

	Standardized Coefficient	p	Contribution to R^2
Fat Intake g/d trim 3	.30	.012	.082
Fat gain sum 3 fat folds trim 2 & 3 (mm)	.28	.019	.012
Severe Illness trim 2	-.30	.012	.082

57 cases R^2=.30 F=7.0 p<.0001
With the addition of the variable kcal, R^2 increases to .39

Relation of Maternal Pregnancy Food Intake and other Variables to Birth Weight

Despite low energy intake and poor PWG, the mean birth weight (BW), as mentioned, was 3.1 ± 0.5 ($\bar{x}$ ± SD). However, 16% of the entire group and 77% of the LBW group were classified as having intrauterine growth retardation (IUGR), which is highly indicative of maternal malnutrition.

Energy intake during pregnancy was found to be consistently and positively related to birth weight in these mild-moderately malnourished women. Associations of kcal intake/day and kcal per kg/day, and estimated total pregnancy intake with BW were all statistically significant, as were associations between BW and fat and protein intakes in trimester 3, a time when the fetus is laying down fat stores (See Table 4.2).

TABLE 4.2.
Correlations between maternal pregnancy nutritional and other variables with birth weight

Variables	n	Correlation Coefficient†	p
Food Intake			
kcal/d trim 1	84	.29	***
trim 3	123	.20	*
Prot(g/d) trim 1		.30	***
trim 3	123	.23	**
Fat(g/d) trim 1		.31	***
trim 3		.21	*
Total kcal intake for pregnancy		.39	****
Maternal Nutritional Status: pre-pregnancy			
Weight	82	.34	***
Body Mass Index (BMI)		.35	***
Mid Upper Arm Circ. (MUAC)		.32	***
Sum 3 fat folds		.39	***
Height		.22	borderline (.1)
Head Circumference		.36	***
Pregnancy weight gain			
Pregnancy weight gain trim 2		.50	***
Total pregnancy weight gain		.47	***
Disease/Morbidity			
Serious Illness	139	-.24	**
Hemoglobin Level	117	.17	*
Enlarged Spleen (in mother)	109	-.34‡	****
Socioeconomic status	138	.28	**
Age at pregnancy	131	.25	*

p values = * <.05, ** <.01, *** <.005, **** <.0005
† Pearson's correlation coefficients, 2-tailed.
‡ Larger the spleen the lower the BW and the more pre-term and LBW infants born.

A number of interacting variables also affect birth weight. Foremost is gestational age, followed by the mother's nutritional status upon entering pregnancy. Not only is recent nutritional status important, as represented by pre-pregnancy and 1st trimester weight and fat stores, but height and head circumference represent long term nutritional experience. While height is only marginally associated with BW, pregnancy weight gain is a much stronger predictor of BW.

Socioeconomic status, and all that it encompasses (e.g. better diet, literacy, food, housing, sanitation and health care) correlates with BW. Finally, anemia and severe illness, particularly late in pregnancy, each have a negative effect on BW.

Variables related to BW were examined in a multiple regression analyses to determine their relative order of importance. In descending order, total pregnancy energy intake (kcal), severe illness in trimester 3 and body fat stores in trimester 1 account for nearly a third of the variation in BW (see Table 4.3).

TABLE 4.3.
Multiple regression analysis for birth weight

Variable	Standardized parameter estimate	p	Contribution to R^2
Total kcal in pregnancy	.38	.003	.136
Kcal/kg trim 1	.20	.108	.037
Sum 3 fat folds trim 1	.24	.050	.056
Severe illness trim 3	-.26	.042	.061

57 cases; R^2 =.28 F =4.99 p <.001

Thus, maternal energy intake, maternal size upon entry into pregnancy, pregnancy weight gain, and severe illness (negative) predict birth weight.

Although a woman may produce an infant of normal or near normal birth weight, she does so at the expense of her own body mass and activity level, entering lactation with poor fat reserves. A behavioral response, identified by time allocation (T.A.) studies is that women, late in pregnancy and early in lactation, double their inactive time. Such activities as child care, food production, agricultural work, and cash labor are reduced. Additional discussions of T.A. studies of pregnant women are found in Chapters Seven and Eight.

CURRENT ANALYSES

The current analyses examine more closely maternal body weight and composition changes over the course of pregnancy and lactation in order to better understand the consequences of inadequate energy intake and other factors on both the mother and the infant.

Changes in Weight and Body Composition during Pregnancy and Lactation

Changes in body weight, fat, and muscle during pregnancy and lactation take place in the context of progressive lowering of food intake during pregnancy and then a return to pre-pregnancy intake levels during lactation. Pre-pregnancy mean daily intake is approximately 1761 ± 375 ($\bar{x} \pm SD$) kcals, 76% of the FAO/WHO/UNU recommended intake (3). By the third trimester, women ingest a mean of 1,360 ± 523 kcals/day. Mean daily intake over the entire pregnancy is 1,455 kcals. These intake levels include the drought and non-drought periods which are later disaggregated for further analysis. At this low level of energy intake, micronutrient deficiencies present in the diet, become even more severe, particularly in the cases of zinc, B_{12}, iron, calcium, vitamin A, and riboflavin. An increased goiter rate among pregnant women compared to non-pregnant women (24% vs. 15%), points to iodine deficiency (See Chapter Two).

Pregnancy Weight Gain

During the first trimester there is no weight gain and even slight weight loss, followed by a rapid increase during the fourth through seventh months of pregnancy and then a leveling off of weight gain (see Figure 4.1). During the last month, there may be up to a 0.5 kg decrease in weight. About 4% of women lose or gain no weight during pregnancy, whereas approximately 3% experience a net weight loss. Only 8.4% gain over 10 kg (see Table 4.4).

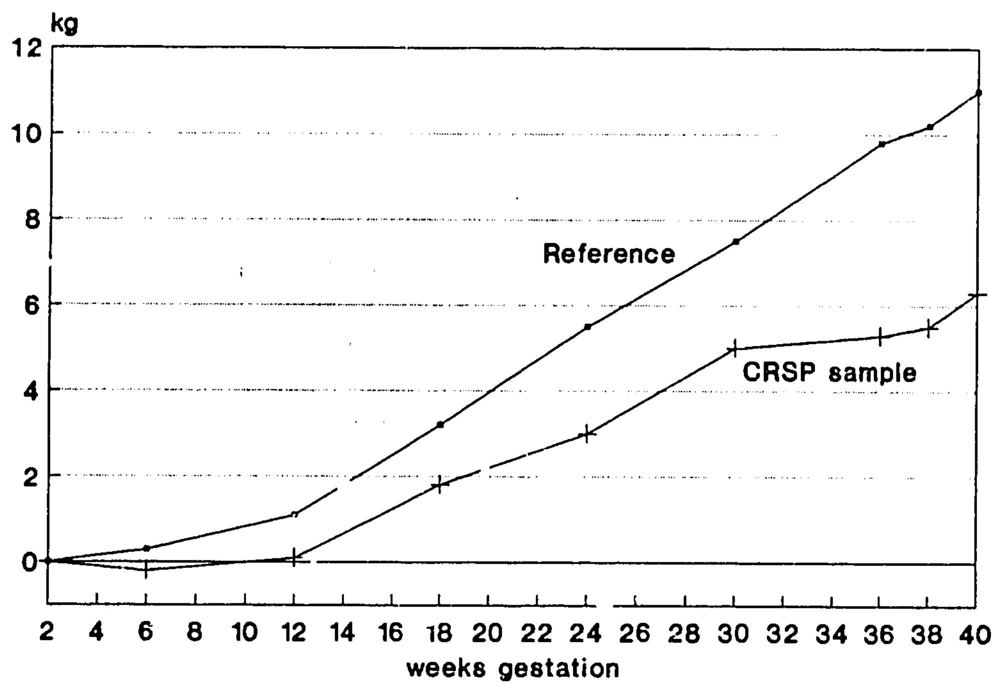

FIG 4.1. Prenatal weight gain in the CRSP sample compared to reference weight gain

TABLE 4.4.
Frequency distribution of pregnancy weight gain

	n	%
No weight gain	4	4.2
Weight loss	3	3.2
Weight gain		
1.0 to 6.9 kg	46	48.4
7.0 to 9.9 kg	40	35.8
≥10 kg	2	8.4

Weight and muscle and body fat changes based on anthropometry are presented in Table 4.5. Pregnancy weight gain is below the currently recommended 11.5 to 16 kg gain for underweight women and 7 to 11.5 kg gain for so called "normal" size women (4). Mirroring the fat changes, mean upper arm circumference (MUAC) decreases by 1.4 cm.

TABLE 4.5.
Pregnancy weight and fat changes in 139 rural Embu women

Measurements	Interval	Change	Range
Weight gain (kg)	trim 1 to 15d ptb*	6.3 ± 3.4	-5 to 14.0
	trim 2 to 15d ptb	5.8 ± 3.2	-3.9 to 11.9
Muscle			
Arm muscle area (AMA) cm2	trim 1 to 2d ptb	-1.9 ± 5.3	-3.8 to 0.2
Body Fat			
Sum 6 fat folds (mm)	trim 2 to 15d ptb	-3.5 ± 11.5	-45.4 to 17.0
% BW as fat	pre-pregnant to trim 3	-2.4 ± 3.1	-7.5 to 7.7
Postpartum (pp) Net pregnancy gain			
Weight	pre-pregnant to 2-8d pp	1.5 ± 3.1	-7.5 to 5.0
Net % fat change	pre-pregnancy 2-8d pp	-1.1 ± 5.2	-4.7 to 4.8

* ptb = prior to birth

Changes in body fat, expressed as the sum of six fat folds (biceps, triceps, subscapular, supra-iliac, thigh and abdominal) increase in the second trimester, followed by a decrease in the third trimester, all statistically significant changes. As a reflection of the fat changes, the MUAC declines steadily in the latter part of pregnancy. Also contributing to the decrease in MUAC is a slight decrease in the arm muscle area (AMA) in the third trimester. By the time lean body mass or muscle is drawn upon, fat store depletion is advanced and is indicative of the severity of energy deficit among these women.

Thus, given low pregnancy energy intake, fetal growth is achieved in large measure through utilization of maternal fat reserves and lastly muscle. Loss of body mass (fat and muscle), plus doubling of inactive time, as shown by time allocation studies, appear to be the main adaptations to low intake. There is no compensatory lowering of resting energy expenditure (REE) in the Embu women as was observed in pregnant malnourished Gambian women (5) (see Chapter Seven). Additionally, based on a small pilot study, the women do not work more efficiently than better nourished women. Measured energy expenditure values obtained during the performance of household tasks agree closely with published values as reported in the 1987 Kenya CRSP Final Report.

Impact of drought-related food shortage on pregnancy outcome

It is informative to re-examine in greater detail, the effects of the severe drought-associated food shortage on pregnancy outcome for women who passed through the food shortage period during their third trimester of pregnancy. In contrast to the "unexposed" group, daily intake of the "exposed" group decreased to a mean daily value of 1147 kcal in trimester 3, and 1550 kcal in lactation. As a result, they experienced a reduction in their pregnancy weight gain (see Table 4.6). Moreover the percent of IUGR infants, born between 2500 to 2800 g, nearly doubled from 16% to 28%. Further cohort analyses are needed to quantify the effect of the food shortage on lactating women and the growth of their infants.

TABLE 4.6.
Energy intakes, and weight changes for women during and after the severe food shortage in late pregnancy and early lactation.

	Maximum food shortage period Oct-Dec 1984		Post shortage period Jan-March 1985	
Mean kcal/d	Mean	± SD	Mean	± SD
Pregnancy	1147	386	1360	523
Lactation	1550	674	1953	467
Pregnancy weight change (kg)				
3rd trim	1.8	2.0	2.7	2.1
9th month	0.3	1.4	1.2	0.9

Differential Weight Gain in Larger versus Smaller Women

Traditionally, uniform recommendations are given for weight gain and food intake in pregnant women of varying nutritional status, i.e. malnourished vs well nourished. However, more recent recommendations reflect the idea that higher energy intake and weight gain would seem to be indicated in malnourished women to assure normal weight newborns and to prevent further maternal depletion. The following analyses examine PWG not only in lighter and heavier women, but also in shorter and taller women. This stratification scheme is relevant to the high prevalence of stunting among the Embu.

Smoothed weight and MUAC change curves, using running medians, were generated for maternal weight and MUAC, at the 25th, 50th and 75th percentiles for pre-pregnancy values. The approach was designed to be able to depict different rates and changes in maternal weight and fat stores[2] during pregnancy and include only women giving birth to full term, normal weight infants (>3000 g). The lighter and leaner the women, the more weight they gain and less fat they lose in pregnancy (See Fig. 4.2 and 4.3). When stratifying by maternal height the weight gain is greatest for the shortest women, those under 151 cm (25th percentile); and least for those ≥ 158 cm (75th percentile). For example the women <151 cm increased their weight by 11.8% and the women >158 cm increased their weight by 7% above pre-pregnancy weight. This pattern was also true for body mass index. Also, the taller women experience a larger decrease in MUAC in late pregnancy than do shorter women. For example for the women <151 cm mean MUAC is unchanged, but the women >158 cm decrease their MUAC by a mean of -4.1 cm ($p<.004$). Statistically significant differences in MUAC by strata were demonstrated by t-tests.

[2] MUAC is used as a representation of arm fat stores. Pearson's correlation (2-tailed) for sum of fat fold change versus MUAC change in pregnancy is $r=0.60$, $p<.0001$ ($n=67$)

Furthermore those mothers whose MUAC (presumably fat stores) decreased the most in late pregnancy gave birth to infants with the largest weights, lengths and MUAC (see Table 4.6).

TABLE 4.6
Relationship between change in MUAC in pregnancy and infant size at birth.

Women	Infant	n	r*	p<
MUAC change during pregnancy	vs. birth weight	64	-.29	.02
	vs. birth length	93	-.23	.03
	vs. birth MUAC	62	-.41	.001

* Pearson's correlations: 2-tailed, p<.05

This is not contradictory to what was found in an earlier analysis on the non stratified sample which showed that maternal fat gain in the 2nd to 3rd trimester is positively associated with PWG (see Table 4.2). The fat loss occurs later in pregnancy.

Based on the above observations women who are better nourished at the start of pregnancy (>25th percentile for height, weight, BMI, MUAC) gain proportionately less weight, give up more body fat (based on MUAC) and produce larger babies than women in the lower quartiles. There may be a threshold below which a malnourished women is not able to mobilize energy from her very limited fat stores to support fetal growth. The better nourished women are better able to mobilize energy to support fetal weight gain.

Changes in Body Weight and Body Fat during Lactation

Relative to immediate postpartum weight, mothers experience a statistically significant weight decrease during the first seven months of lactation. Maternal weight then gradually increases returning to pre-pregnancy levels by the eleventh month of lactation. (See Table 4.7).

TABLE 4.7.
Maternal weight, fat and MUAC changes during lactation

	Interval in Lactation	Mean change
Weight change (kg)	7-10 days pp* to 7 mos.	-1.1
	7-10 days pp to 11 mos.	0.8
Fat change (mm) Sum 3 fat folds	7-10 days pp to 3 mos.	-4.7
	3 months to 7 mos.	2.5
MUAC change (cm)	7-10 days pp to 3 mos.	-0.1
	7-10 days pp to 7 mos.	0.3

* pp= postpartum

As for changes in fat folds and MUAC, both decrease in the first 3 months of lactation and then gradually increase up to 7 months. Although mothers appear to be regaining fat, they still remain below the pre-pregnancy level until eleven months postpartum, having lost fat in late pregnancy. The weight and fat loss pattern is not unlike that of women in the USA, except that fat loss in pregnancy tends not to occur in American women (6).

Differential Weight Changes in Lactation by Prior Maternal Nutritional Status

As in pregnancy, women who are heavier, taller, and fatter (larger MUAC) at the start of pregnancy tend to lose more weight in lactation compared to women with lower fat stores, weight and height (Table 4.8). The larger mothers have larger infants who may require more breast milk than smaller infants, imposing a greater nutritional drain on the mother. However, this is conjecture as breast milk intake was not measured. The smaller women tend to gain rather than lose weight during the early weeks of lactation relative to their immediate postpartum weight (see Figure 4.4).

TABLE 4.8.
Changes in maternal weight during lactation stratified by maternal size in trimester one of pregnancy

Stratifiers in Pregnancy	Maternal lactation weight changes (kg) (0 to 11 mos.)		
MUAC trim 1	Mean ± SD	t	p
≤ median	0.3 ± 3.2	2.4	.03
> median	-4.1 ± 5.3	2.4	.03
Weight trim 1			
≤ median	0.5 ± 3.6	2.4	.03
> median	-3.7 ± 4.8	2.2	.04
Height			
≤ median	-1.2 ± 3.5	2.7	.01
> median	-3.1 ± 4.8	2.6	.01
	Maternal lactation weight changes (kg) (4 to 11 mos)		
Weight trim 1			
≤ median	-1.3 ± 2.5	3.2	.004
> median	-5.0 ± 3.7	3.2	.004

Changes in MUAC during lactation vary also by the mother's weight and MUAC size early in pregnancy, and follow the same pattern as weight changes during lactation (see Figure 4.5). The changes seen are statistically significant as evaluated by t-tests (see Table 4.9). Women with MUAC or weight above the median values in trimester one have a greater decrease in MUAC (presumably fat) during lactation compared to women with MUAC or weight below median values. Better nourished women have more energy reserves to utilize in supporting their infants' growth, mediated most likely through the volume and composition of their breast milk.

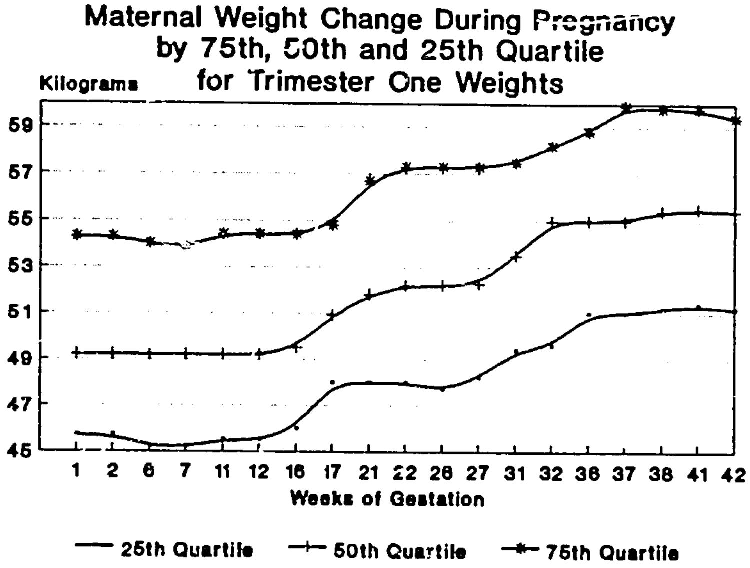

FIG. 4.2

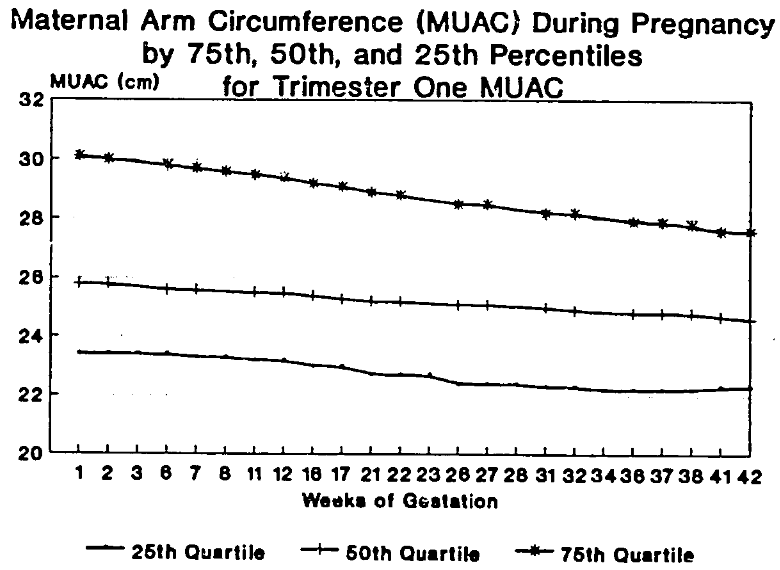

FIG. 4.3

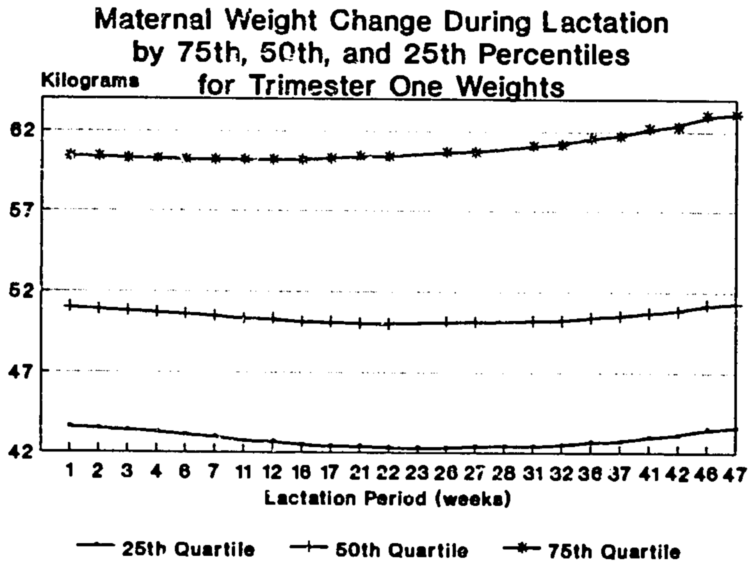

FIG. 4.4

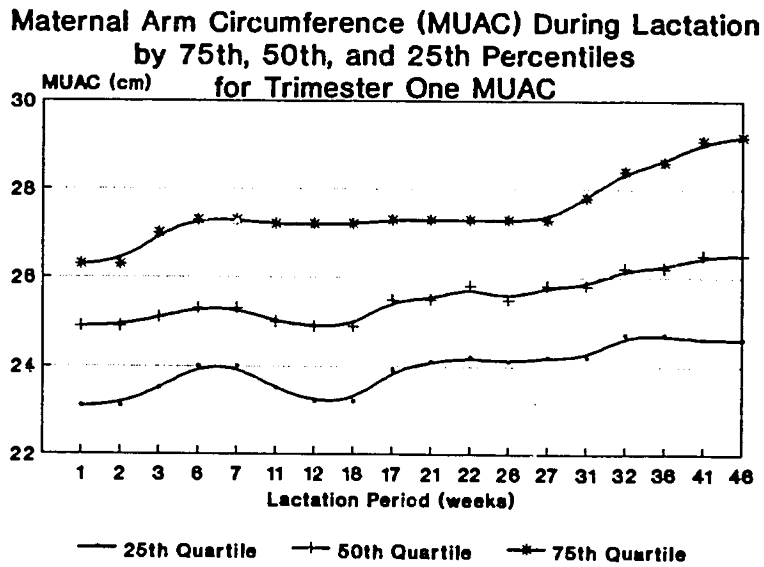

FIG. 4.5

TABLE 4.9.
Changes in maternal MUAC during lactation stratified by trimester one weight and MUAC

Stratifiers in pregnancy	Maternal lactation MUAC changes (cm) (0 to 7 months)		
Weight trim 1	Mean ± SD	t	p
≤ median	-1.4 ± 1.0	3.5	0.003
> median	-3.1 ± 1.4	3.5	0.002
MUAC trim 1			
≤ median	-1.7 ± 0.9	2.6	0.02
> median	-3.6 ± 2.1	2.5	0.02

Diet quality: Effect on Reproductive Outcome

In view of overall low mean daily food intake and particularly low intake of animal source food and iodized salt, a concern about diet quality is raised in relation to pregnancy outcome. Analyses of selected micronutrients i.e., zinc, B_{12}, and iodine have been initiated in order to explore the relationship of these to infant and maternal reproductive outcomes. Results reported here, although preliminary, show that micronutrient deficiencies play a role in adverse pregnancy outcomes.

As a broad indicator of diet quality, fat and animal protein intake, above and beyond their contribution to energy intake, promote pregnancy weight gain and birth weight as noted earlier (see Tables 4.1 and 4.2). Animal protein contains micronutrients (iron, zinc, B_{12}) and fat is a concentrated energy source.

Iodine

As presented in the chapter on Food Intake, iodized salt is used by only 27% of households and goiter prevalence in pregnant women is 24%. About 20% of the pregnant and lactating women were found to have low T4 levels and almost all to have low Free T4 values, a sensitive measure of thyroid status. Because SES is strongly correlated with use of iodized salt, SES is controlled for in the relevant analyses and partial correlations presented (see Table 4.10).

TABLE 4.10.
Iodized salt use and thyroid hormone levels in Kenyan women

		TSH	FrT4	T4	% <RDA iodine intake*	% with goiter
Normal lab values†		≤3.9 μU/dl	0.7-1.7 ng/dl	75-175 μU/dl		
Group	n	% elevated	% low	% low		
NPNL	213	0	88	21	72	15.1
Pregnancy	149	2	98	22	78	24.3
Lactation	139	0	99	20	77	22.0

* RDA from FAO/WHO/UNU, percent deficient is an under estimate because of low water concentrations of iodine in Embu district and therefore iodine content of food would be low.
† Established for methods used in laboratory (see Food Intake chapter).

Thyroid enlargement in pregnant women in their first and second trimesters and in lactating women was negatively associated with increase in MUAC and fat gain during pregnancy and lactation (see Table 4.11), as was use of non iodized salt and elevated TSH (an early sign of hypothyroidism) in pregnant women. Iodized salt use and T_4 levels were related to PWG and to fat deposition in lactation expressed by increased fat fold thickness and MUAC.

With regard to the newborn, iodized salt use in pregnancy correlates positively with gestational age. Thyroid stimulating hormone (TSH) level showed a significant partial negative correlation with birth weight when controlling for SES. Finally, goiter was positively associated with a history of an increased number of stillbirths and miscarriages (see Table 4.11).

TABLE 4.11
Relation of maternal iodized salt use and thyroid variables with maternal MUAC and weight in pregnancy and lactation (controlling for SES).

		n	r	p<
Pregnancy				
Iodized salt use	vs. MUAC change trim 2	56	.48	.0002
Non iodized salt	vs. MUAC change trim 2	24	-.56	.005
TSH	vs. MUAC pregnancy	101	-.24	.01
Thyroid size	vs. MUAC change trim 2	37	-.38	.02
T4	vs. Fat fold change trim 2	39	.39	.02
Neonate				
Iodized salt use	vs. Gestational age	137	.17	.05
T4	vs. Gestational age	131	.18	.04
TSH	vs. Birth weight	126	-.28	.001
Thyroid size	vs. No. stillbirths	80	.20	.07
Lactation				
Iodized salt use	vs. change in sum fat folds	24	.44	.04
Thyroid size	vs. MUAC	37	-.55	.001
T4	vs. Weight change	12	.58	.06

partial correlations, $p<.05$

Maternal Vitamin B_{12} Intake

Based on food intake measurements, B_{12} intake is extremely low in all target individuals, but particularly in pregnant and lactating women. Approximately 90% of pregnant and lactating women ingest less than 2/3 of the recommended intake for vitamin B_{12}. Breast milk samples from these women were found to be deficient in vitamin B_{12}[3] (7) (see Table 4.12 and Figure 4.6). For example, their levels corresponded to those seen in rural poor vegetarian Indian women (8). The main clinical expressions of B_{12} deficiency observed in the study women were macrocytic anemia in 8.4% with hypersegmented polymorphonuclear leukocytes (PMN) in 4% of these women. Deficient levels of folate which can also cause macrocytic anemia were present in 23% of the pregnant women.

[3] Breast milk samples were analyzed for vitamin B_{12} by Dr. Susan Oace, Dept. of Nutrition, University of California Berkeley, CA.

Women with macrocytic anemia with or without hypersegmented PMN cell nuclei (presumably severe B_{12} deficiency), or just B_{12} deficient intakes, were noted to have more IUGR infants and stillbirths than those with no B_{12} deficiency or blood abnormalities. Pearson's correlations ranged from r=.19 to .21, $p<.05$ (n=56-96). However vitamin B_{12}, intake per se, did not correlate with birth size or gestational age.

TABLE 4.12
Vitamin B_{12} levels in breast milk of rural Kenyan women in Nutrition CRSP* (pg/ml)

Mean and SEM pg/ml	Overall B_{12} levels	B_{12} in early lact	B_{12} lact. 1-4 mos
Kenyan women	165±10	237 ± 18	131±18 to 127±18
USA women (Thomas et al. 1979)	605±185	1220 ± 410	610±170

* Normal levels ≥ 500 pg/ml.

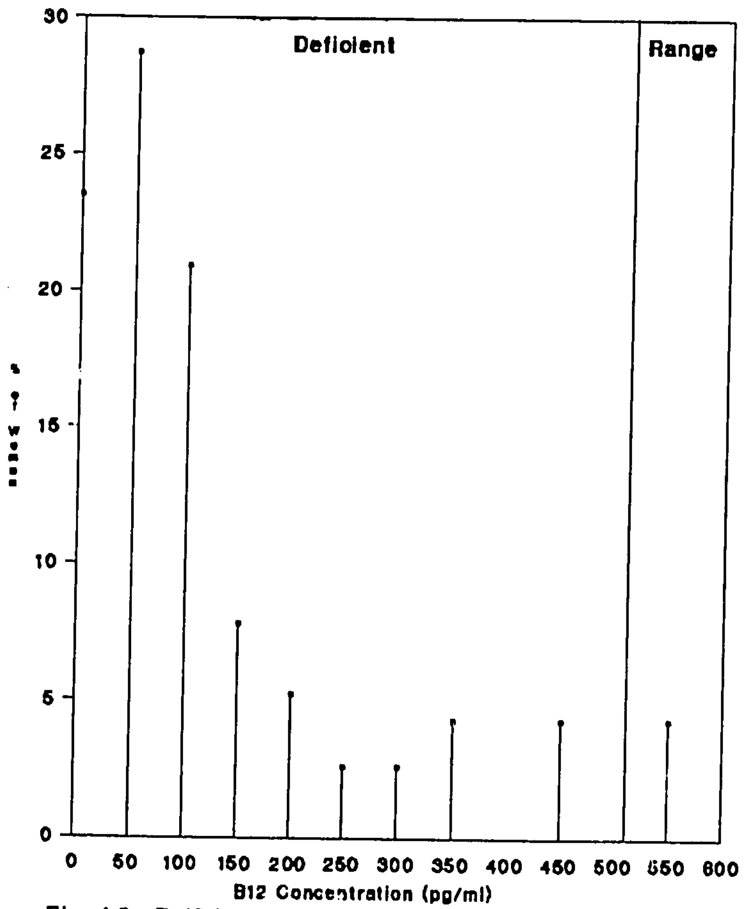

Fig. 4.6: B-12 Levels of Breast Milk in Kenyan Women
(3-4 Samples per 115 Women)

Maternal Zinc Intake

Maternal zinc intake in pregnancy, particularly in trimester 2, shows a positive and nearly statistically significant association with birth weight. With length, the association is stronger and statistically significant (see Table 4.13).

TABLE 4.13.
Correlations for infant weight and length at birth by maternal zinc intake during pregnancy (trim 2) with and without controlling for kcal intake

	n	zinc	< p value	zinc controlling for kcal
Birth weight (kg)	113	.17	.07	NS
Birth length (kg)	111	.22	.02	NS

The association of zinc with BW and length are no longer statistically significant when the effects of kcal are controlled for. These analyses will be repeated using bioavailable zinc, taking into account the high phytate and fiber content and low animal protein content of the diet.

Anemia

Anemia is present in 37% of pregnant women due mainly to iron deficiency, B_{12} and possibly folate deficiency as well. Malaria and hookworm infection also contribute to the problem. Anemia has a strong negative effect on birth weight particularly when analyzed by odds ratio and logistic regression as presented later in this chapter. Anemia, particularly associated with vitamin B_{12} deficiency such as macrocytosis and hypersegmentation of PMN nuclei, is a predictor of IUGR and stillbirth [Pearson's correlations r=.19 to .21, p<.07 to .0007 (n=96)].

Effect of Pregnancy and Lactation Food Intake on Infant Growth

Infant growth is considered a reproductive outcome and a measure of lactation performance. This topic is discussed in Chapter Five, "Evolution and Onset of Stunting".

MATERNAL ANTHROPOMETRY AS A PREDICTOR OF RISK FOR ADVERSE PREGNANCY OUTCOMES

Recent attention has been called to the possible predictive value of simple maternal anthropometric indicators for identifying risk for poor maternal and infant pregnancy outcomes. Using simple anthropometric indicators such as weight or MUAC would allow village level workers or traditional midwives to detect women at risk for poor pregnancy

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outcomes and promote early referral for intervention. This section summarizes an analysis of the use of such indicators and reproductive history to predict infant and maternal reproductive outcomes.[4] To date, infant outcomes have received more attention than maternal outcomes. For infants, LBW, prematurity, IUGR, stillbirths, and perinatal deaths are considered. For maternal outcomes, only delivery complications are considered.

This analysis is based on data from the 140 pregnant women described in the previous section. For the set of outcomes that include perinatal deaths, delivery complications and stillbirths, factors associated with these abnormal pregnancy outcomes are merely compared to normal pregnancies, as these adverse outcomes are relatively infrequent in the study sample. Maternal anthropometry, reproductive history, and other variables are included.

Infant Outcomes

Birth weight was constructed as a dichotomous variable to indicate "low" versus "normal" birth weight, (<2500 g vs. $\geq$ 2500 g). Pre-term is defined as GA <37 weeks and was measured by the Dubowitz scale (9). Of the live births, 10% were LBW. Infants with IUGR, using Williams criteria (2), are far more common in this sample than LBW infants due to prematurity. This definition has an advantage in that it considers a full continuum of birth weights at all levels of gestation. Of all the live births, 16% are IUGR and 77% of LBW infants are IUGR. Pre-term infants and IUGR infants may arise from a different set of factors and have different prognoses and complications. For example, IUGR is closely and primarily associated with maternal malnutrition and infection during pregnancy (10).

Predictor Variables

The primary predictors of pregnancy outcome considered are maternal anthropometric measures taken in the pre-pregnancy period and in each trimester of pregnancy. These include height, weight, body mass index (BMI), and MUAC. As a representation of fat stores and muscle mass, MUAC is used, as it would not be feasible or affordable for village level health workers to use fat fold calipers. Also, MUAC correlates very strongly with body weight and BMI in the Kenya CRSP sample, r= .80 to .90, p<.001 (n=138).

Both maternal weight and BMI have significant independent associations with LBW outcomes. Although BMI is negatively correlated with the occurrence of LBW outcomes, the association is due primarily to the influence of the maternal weight component of the BMI. Therefore, it is simpler, both in terms of interpretation and practical field considerations, to use weight rather than BMI. Other predictor variables used in this analysis are maternal age, reproductive history and anemia. This latter predictor also poses

[4] Analyses based on doctoral dissertation research by Duncan Ngare, DrPH, UCLA and preliminary findings for a WHO/Mothercare Project supported by USAID/Health.

practical problems, such as devising an affordable simple field method to obtain hemoglobin levels.

Estimate of Risk for LBW Births Based on Maternal Anthropometric Indicators

Odds Ratios (OR)

To estimate relative risk two-way associations between each of the outcome variables (LBW, prematurity and IUGR) and each of the anthropometric predictor variables (height, weight and MUAC) are assessed from analyses of contingency tables. Odds ratios are calculated based on the entire sample and when the data are stratified by maternal height, age, and parity.

Maternal anthropometry is dichotomized by using the 25th and 50th percentile values for each measure. For example, within the distribution for maternal height, a height of 151.0 cm represents the 25th percentile (i.e., short women), while women with values greater than 151.0 cm were classified as "normal". The odds ratios and confidence intervals for each of the contingency tables described above are presented in Table 4.14.

TABLE 4.14.
Odds ratios for low birth weight and IUGR infant outcomes in Kenyan women.

Low Birth Weight*					
Weight (kg)	Percentile	Cut off	n	O.R.	95% CI
Pre-pregnancy	25	45.0	56	9.1	1.4 - 57.6
Trimester 2	25	45.8	96	4.2	1.0 - 17.1
Trimester 3	25	50.8	138	5.6	1.2 - 26.3
MUAC (cm)					
Trimester 1	25	23.7	115	3.5	1.2 - 11.8
Trimester 2	50	25.3	105	12.6	1.6 - 101.2
Trimester 3	50	25.1	138	5.8	1.3 - 27.1
Intrauterine growth retardation (IUGR)					
	Percentile	Cut off	n	O.R.	95% CI
Height (cm)					
Pre-pregnancy	50	154.5	138	2.2	0.9 - 5.5
MUAC					
Trimester 2	50	25.3	115	2.5	0.9 - 7.2
Lactation	25	24.2	75	2.8	0.9 - 8.6

* No O.R. were significant for pre-term only.

Regardless of when maternal weight is measured during the course of pregnancy, women under 45 kg have higher odds of having a LBW infant. As maternal weight increases, during the second and third trimesters, a shift occurs in the proportion of women who are at risk. During pre-pregnancy the odds are nine fold. By the second and third trimester the odds are four fold and six fold greater that a woman below the first quartile will have a LBW infant. For trimester two the cut off is 45.8 kg and for the third trimester, 50.8 kg. These data indicate, then, that low maternal weight prior to and at any time during pregnancy places a women at a relatively high risk for LBW infant outcomes. However, the wide confidence intervals for some of the OR indicate that the significance of the OR may be low.

Examining the use of MUAC as a predictor, women with small compared to large MUAC (<25 cm vs. ≥ 25 cm) are at a greater risk for a LBW infant outcome. The risk of a low versus normal birth weight outcome increases six times for women with a MUAC under 25 cm in trimester 3. Similar findings were cited by D. Ngare in his doctoral research which included this same group of women. In regard to height, those women below the median (154.5 cm) have a two fold risk for producing a LBW infant. The odds ratio is 2.0 with a 95% CI from 0.9 to 5.5.

Stratified Odds Ratios

To control for the potential confounding effects of maternal height, age, and parity on infant outcomes as predicted by maternal weight and MUAC, stratified analyses were carried out. Although there is a trend toward higher odds ratios among the shortest women ($\leq$ 151.0 cm) compared to the tallest women ($\geq$ 158.5 cm), the chi-square tests indicate that none of these differences are statistically significant at the $\alpha = .05$ level. The same is true for maternal age and parity.

Logistic Regression Analyses for Infant and Maternal Outcomes

Logistic regression analyses were used to estimate the likelihood of a negative pregnancy outcome which is affected by maternal weight and MUAC or height when controlling for the influence of modifying variables other than anthropometric measurements. This controlling technique was applied to the prediction of LBW, IUGR, and maternal delivery complications (see Table 4.15).

Low Birth Weight

The model for LBW shows that body mass index, parity, socioeconomic status, and hemoglobin significantly affect the odds of the birth of a LBW infant. Arm circumference and maternal age are also included in the model as control variables. The joint effect of all of these variables is statistically significant, as indicated by the log likelihood and s-score statistics. The model correctly classifies 86% of the cases (see Table 4.15). The odds of a LBW infant versus a normal birth weight infant being born decrease with increasing values of maternal body mass index, parity, SES, and hemoglobin.

Maternal Delivery Complications

The model for delivery complications mainly c-sections and breech presentation shows that maternal height, the number of previous stillbirths and parity affect the risk of problems at delivery. The joint effect of all these variables is significant. The model correctly classifies 84% of the cases. The odds of delivery complications decrease with increasing height and parity and increase with age and previous number of stillbirths (see Table 4.15).

TABLE 4.15.
Logistic regression models to predict the birth of LBW and maternal delivery complications

Outcome	Variable	Parameter Estimate	Standard Error	Prob. Chi-sq
LBW (n=110)	Intercept	14.80	7.25	*
Chi-sq* = 21.0, p<.001 (6DF) concordance 86%	BMI trim 2	-0.54	0.31	*
	MUAC trim 1,2	-0.02	0.30	NS
	Parity <3	1.57	0.86	*
	Hemoglobin	-0.34	0.20	*
	SES	-0.06	0.03	*
	Maternal age	0.09	0.07	.10
Maternal Delivery complications	Intercept	12.52	12.6	NS
	Height	-0.11	0.08	NS
Chi-sq = 10.4 p<.03 (4DF) concordance 84%	Age	0.09	0.07	NS
	Previous complication	1.22	0.53	*
	Parity	-.28	0.17	*

* Chi-sq for log likelihood ratio

Use of Non Anthropometric Indicators as Predictors of Reproductive Outcome

Questions about reproductive history such as previous poor pregnancy outcomes, i.e. stillbirths or obstructed labor or key observations such as goiter can be extremely valuable in detecting risk. Because the number of stillbirths, miscarriages, and abortions were small (n=5) comparisons of relevant factors are made with normal pregnancy outcomes and t-tests performed on the mean values (see Table 4.16). Despite the small number of abnormal outcomes, statistically significant differences are seen.

For stillbirths and miscarriages, there are a greater number of past stillbirths, miscarriages, abortions, and mothers with visible goiters. This suggests that questions about the use of iodized salt in an iodine deficient area are useful and obtainable as risk indicators by village level workers.

TABLE 4.16.
Comparison of factors associated with abnormal outcomes of stillbirths, miscarriages, abortions

Outcomes:	Abnormal n=5	Normal n=125	t	p
History or observations	%	%		
History of stillbirth, abortion, miscarriage	12	0.5	2.9	.002
No. previous abnormal deliveries	18	0.3	0.5	.017
Visible goiter	14	0.2	0.4	.07
Non iodized salt use	47	35.0	13. 0	.016

Risk for Infant Perinatal Deaths

Perinatal deaths occurred in five infants, giving a perinatal death rate of 37 per 1,000 live births. As with pregnancy wastage, because of the small number of deaths only a list of relevant factors is presented (see Table 4.17). There was a predominance of LBW and preterm infants and twins among the deaths. Mean daily kcal intakes and PWG were very low, one woman lost 3.5 kg, another woman gained 2.7 kg and for the twin pregnancy, the gain was only 7.3 kg. Parity in two of the women was twelve and nine. Deaths of male infants exceeded those of female infants.

TABLE 4.17.
Factors associated with infant deaths

			Twins	
Infant cases:	A	B	C and	D
SES index	87	91	70	70
BW (kg)	1.6	3.3	1.8	2.2
GA (wk)	29	38		34*
Sex	F	M	M	M
Kcal/day-pregnancy				
trim 1	1174	1032	1349	
trim 2	1122	1912	2611	
trim 3	1277	890	1092	
Iodized salt use HH (g)	0	11	42	
Pregnancy weight gain	2.7	-3.5	7.3	
History				
Parity	12	2	9	
Normal births	10	2	7	
Menarche - onset (yr)	18	14	14	
Abnormal deliveries	0	Breech with c-section	0	

* Dubowitz performed in larger twins only

Conclusions on Use of Anthropometry and Medical History

Thus, using anthropometry, mainly MUAC and weight prior to or during pregnancy and asking selected questions about parity, stillbirths, and previous births of small babies or delivery complications can identify women at risk for poor pregnancy outcomes. The risk of a low birth weight outcome is more than ten times greater for women whose weight during pre-pregnancy and all trimesters of pregnancy are below the first quartile (25th percentile). Arm circumference (<25 cm) is also a useful indicator and behaves like weight in risk detection.

Questions about reproductive history when combined with anthropometry increase the ability to determine risk. Finally, height <25 percentile or lowest quartile, plus history of a previous abnormal delivery are useful indicators for predicting abnormal deliveries, mainly c-sections, and allowing for early referral to skilled obstetrical care. Adding hemoglobin determination improves the ability to detect risk for the birth of LBW and IUGR infants.

Field testing of the above risk indicators will have to be carried out to actually test their ability to detect high risk situations. Equally important is the necessity to devise appropriate interventions and referral sources.

SUMMARY

The most striking findings among this group of already chronically malnourished women is that they produce infants of normal or near normal birth weights. Despite their progressive lowering of energy intake in each ensuing trimester of pregnancy and their poor pregnancy weight gain (half of what is recommended) they then give birth to infants that have a mean birth weight of 3.1 kg, only 10% of whom are low birth weight. These women start childbearing in their late teens and have an almost continuous cycle of repeated pregnancies and lactation with high overall parity of six to seven children.

The analyses have attempted to address how these women accomplish such relative reproductive "success" and what the consequences are of poor pregnancy intake and weight gain. Several clear findings emerge.

Energy intake is an important determinant of pregnancy weight gain and of birth weight. The relationship between food intake, in the pre-pregnancy period and throughout pregnancy relates to maternal weight gain and fat gain and net postpartum pregnancy weight and fat gain. Food intake during pregnancy also affects the infant during its first six months of growth, as well as the nutritional status of the lactating woman. Diet quality especially animal protein and fat intake, are of particular importance, because of their micronutrient content and the concentration of kcals in fat. Socioeconomic status is an important determinant of whether or not the mothers receive iodine, salt, animal protein and fat in their diet. It also emerged that B_{12}, iodine and zinc deficiencies may play a role in reproductive outcome and the growth of the infant.

Pre-pregnancy size was found to be of importance in determining birth weight and infant growth from 0 to six months. The size of the mother in pre-pregnancy, her BMI, weight, height, head and arm circumferences, fat stores, and arm muscle area, all relate positively to birth weight. The mother's weight and height explain a fifth to a third of the variance in the infant's birth weight and size at six months.

Illness and anemia, especially macrocytic anemia presumably due to B_{12} deficiency and possibly folate deficiency, adversely affect birth weight. Fever and clinical malaria and other severe illness especially in the second half of pregnancy, all have a negative impact on pregnancy weight gain, gain in fat stores and the infant's birth weight.

A closer look at the infants outcomes reveals that of the 10% of infants that are low birth weight, 77% of these have IUGR or are below tenth percentile of weight for their gestational age. Including infants weighing between 2500 - 2800g, but below the tenth percentile of weight for GA, the overall IUGR group is 16% of all infants born, which implies widespread maternal malnutrition, malaria and infection. Another expression of IUGR is that the average birth length of all infants is only 20th to 30th percentile or a mean z-score of -0.8, which may in addition to energy deficit reflect possible intrauterine micronutrient deficiency.

The stratification of women by their size just prior to or at the onset of pregnancy is instructive. The women who are the smallest and lightest (<25th quartile), with the least amount of fat stores and who give birth to infants ≥3000 g are seen to consistently gain a greater amount of weight and lose a lesser amount of fat late in pregnancy, compared to women who are above the 75th quartile. Thus uniform recommendations for weight gain and food intake for women are not reasonable. They must be tailored to the pre-pregnancy or early pregnancy size of the women. Also, the women who are above the 75th percentile or have the largest height, weight and MUAC are the ones that lose the most fat during pregnancy and have the largest infants at birth. This is not to be confused with the fat gain in the second trimester. The fat loss occurs late in pregnancy. There is a threshold beyond which the smaller women cannot furnish energy from their fat stores to support the pregnancy.

In general, the women enter lactation with only 1.5 kg extra weight or fat, which furnishes about 13,000 kcal to be distributed over the 15-17 month cycle of pregnancy and lactation. This provides only 20 extra kcals per day toward milk production. Lactation is further discussed in Chapter Five.

Another important mechanism for coping with low energy intake in late pregnancy and early lactation is that physical activity is reduced and women double their inactive time, at the expense of household care, child care, economic and agricultural activities and food preparation. In particular during illness the pregnant women requires more help and reassigns her daily tasks to a much greater extent than do non pregnant women. Also, examination of resting energy expenditure shows that there is no compensatory lowering of the REE, which has been hypothesized as a cost free adaptation to allow more available energy for the needs of pregnancy, lactation and the daily activities of living. The slight rise seen in REE is commensurate with weight gain during pregnancy and then drops slightly during lactation. On a per kg basis there is no change at all seen in the resting energy expenditure. Nor do pregnant women work more efficiently as documented by a small pilot study.

A practical application of the Nutrition CRSP findings is the relationship of simply obtained anthropometric indicators prior to or during pregnancy, which can be used to predict risk for poor pregnancy outcomes such as LBW,and IUGR and maternal delivery complications. These indicators are MUAC, height and weight. BMI, if it can be calculated, gives an even better indicator of risk. Short stature in the mother, below the 25th percentile, carries a high risk for abnormal labor and delivery, particularly obstructed labor requiring c-section. Adding a hemoglobin determination and simple questions about past reproductive events and abnormalities and simple observations such as the presence of goiter, improves the prediction of risk even more. Field workers can be trained to use these indicators.

Implications and possible interventions will be discussed in a final chapter. However, the findings point to a need for intervention starting very early in the life of the female. There must be careful monitoring of food intake and weight gain, and an increase in the quantity and quality of the diet, including use of iodized salt and treatment of anemia, to improve the size of the women upon entering the reproductive cycle. Such interventions are necessary to reverse a pattern of body mass loss and decreased physical activity which are harmful to the women and their families, and probably affects their ability to lactate optimally to support the growth of their infants.

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CHAPTER FIVE.
EVOLUTION AND ONSET OF STUNTING IN RURAL KENYAN CHILDREN

INTRODUCTION

Chronic malnutrition as expressed by stunting and underweight is far more prevalent than severe protein energy malnutrition (1). Coupled with infection, it is the leading cause of growth failure among children in less technically developed countries. Stunting is a widespread problem in Kenya, particularly in Eastern Province and the study area (2). The prevalence of stunting in the CRSP sample is presented in Table 5.2.

The longitudinal design of the CRSP study allowed us to observe three cohorts of children of different ages and their biologic parents from 247 households. Food intake, body size, morbidity, and a number of household and environmental characteristics were measured longitudinally for one to two years. This design allowed us to follow growth patterns over time and over the range of childhood stages of growth and development and to examine determinants of growth. A strength of this study was the ability to follow mothers during the course of pregnancy as early as the first trimester and then follow the newborns for the first six months of life. Follow-up studies of the toddlers and schoolers three to five years after the initial field study, allowed for long term observation of growth, which is included in this report. Weight is considered along with stature, as the two are closely intertwined and weight status is a reflection of low stature for age.

Diet

Detailed information about the diet is found in Chapter Two. Of greatest relevance to growth is that the diet is generally deficient in energy and low in fat for all age groups. With extremely low intake of animal source products (i.e. eggs, meat and fish), vitamin B_{12}, zinc and iron intakes are also deficient. Milk is used to a limited extent and is the main source of animal protein in the diet. Furthermore, zinc and iron bioavailability are low because of high fiber and phytate in the diet. Vitamin A, calcium and riboflavin intake are also low, and there is evidence of mild iodine deficiency in the area. Anemia is prevalent, due mainly to nutritional causes, particularly iron and B_{12} deficiency, but also due to malaria and hookworm.

All infants are breast fed on demand throughout the day and night for a mean duration of 17 months. Supplemental cow's milk and maize or millet gruels, some fermented, are introduced between the second and third months of life, but demand breast feeding is maintained at all times. Supplemental feeding is discussed in greater detail later in this chapter.

METHODS

For a detailed description of the methods please refer to the Nutrition CRSP Kenya Project Final Report (1987).

Anthropometry

In brief, anthropometric measurements were obtained once a month with duplicate measurements per subject made independently by two observers. If pre-set limits were exceeded then a pair of measures were repeated and all four values averaged. Quality control procedures showed high agreement between measures of field workers with their supervisors and with each other, and a number of standardization tests and retraining sessions were held periodically throughout the life of the project. Length and height measuring boards were used with a fixed head piece and sliding foot board, with two people carrying out the measurements. Careful attention was paid to head and foot positions and readings were made to the nearest 0.1 cm. Length was measured to the age of 30 months and height thereafter.

Reference data used to assess attained and incremental growth were those of the National Center for Health Statistics (NCHS) adopted by WHO for international use (3). Studies in Kenya of children of privileged families among various tribes, as well as urban groups in Nairobi showed that these populations fit the median values of the NCHS curves and even surpass them. Therefore, we feel this is an appropriate reference (4). For adults the 1959 Metropolitan Life Insurance data, also adopted by WHO, were used for reference purposes (5).

Cohorts

All cohorts were followed from one to two years except for the group of non CRSP adolescents described below. Cohorts of the following age groups were included:

Infants: 130 newborns followed from birth to 6 months of age, having been followed "in-utero" for 6 to 9 months.
Toddlers: 120 followed from 18 to 30 months and a subsample remeasured at age five years.
Schoolers: 138 followed from age 7 to 9 years and remeasured when they reached the ages of 12 to 13 years.
Adolescents: One group is comprised of former schoolers. In addition, a group of non CRSP study pre-menarcheal girls aged 12 to 18 years and an age matched group of menarcheal girls were weighed and measured for height and fat folds.[1] Menarche was based on physical examination and menstrual history.

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[1] Field work carried out by Dr. A Scott and Dr. AAJ Jansen.

Adults: 247 men and 247 women, biologic parents of the target children, were followed for 1 to 2 years.

FINDINGS

Actual stature for Embu children and adults are given in Table 5.1.

TABLE 5.1.
Stature for age in Embu children and adults

	n	Mean age	Male Mean ± SD (cm)		Female Mean ± SD (cm)	
Infants	117	birth	49.3	2.3	48.7	2.3
		6 mos	62.7	2.7	62.4	2.1
Toddlers	118	24 mos	79.8	3.6	78.7	2.8
Schoolers	138	84 mos	113	6.0	112.4	5.5
Teen	70	13.5 years	144	6.7	146.0	4.5
Adult	247	> 21 years	165.4	6.5	154.5	5.5

Mean z-scores for stature and weight are presented for the different age groups (see Table 5.2, Figures 5.1 and 5.2).

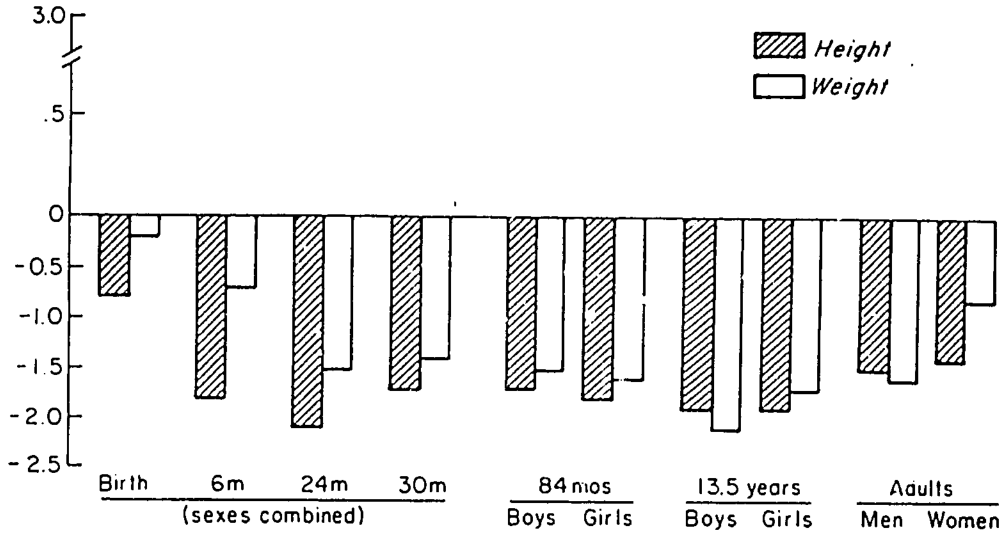


FIG 5.1 Mean z-scores for stature for age and weight for age by age groups

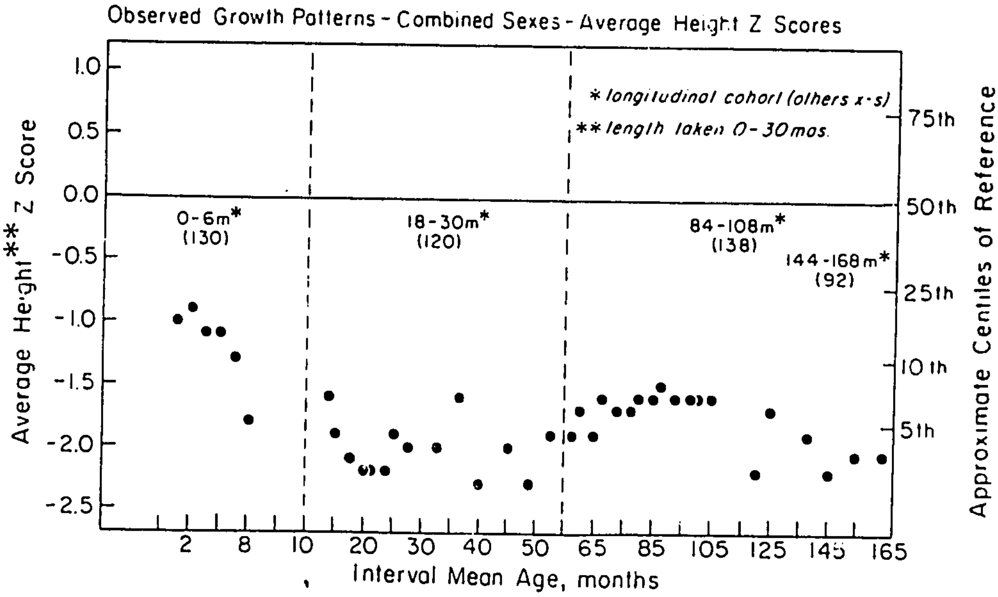


FIG 5.2 Z-scores for average height, by age of Embu Children: 0 to 145 mos.

TABLE 5.2.
Mean z-scores* for height or length, weight, and weight/height by age.

	n	Length or Height mean ± SD		Weight mean ± SD		Weight/ Stature mean ± SD		Percent stunted (M+F)
Infants	117							
Birth		-0.8	1.0	-0.2	1.4	--		14
6 mos		-1.8	1.0	-0.7	1.1	--		28
Toddlers	111							
18 mos		-2.0	1.0	-1.5	0.9	-.43	0.8	23
24 mos		-2.1	0.9	-1.6	0.9	-.20	0.9	
30 mos		-1.7	1.0	-1.4	0.9	-.44	0.7	
Schoolers	138							
84 mos		-1.8	0.9	-1.6	0.8	-.28	0.8	21
96 mos		-1.7	0.9	-1.3	0.8	-.26	0.8	24
108 mos		-2.0	1.0	-1.3	0.8	-.50	0.7	35
Adolescents†	70							
12-14 yrs								
Male		-1.9	0.8	-2.1	0.6	--		--
Female		-1.9	1.9	-1.7	0.8	--		--
Adults								
Male	247	-1.5	0.9	-1.6	0.4	--		13 male
Female	247	-1.4	0.9	-0.8	0.5	--		16 female

* NCHS reference data (3)
† Former schoolers.

Infants as seen in the previous chapter, are born with normal or near normal birth weights, but lengths are lower relative to weight. The mean z-score for birth weight is -0.2±1.4 ($\bar{x}$ ± SD), but for birth length is -0.8±1 (see Table 5.2, Figures 5.5 and 5.6). These represent the 40th and 25th percentiles respectively for weight and length. Mean head circumference at birth is at the 50th percentile. Ten percent of the newborns were low birth weight, and of the LBW group 77% had intrauterine growth retardation (IUGR). Of the total group 16% had IUGR when including infants between 2500 and 2800 g who are below 10th percentile weight for gestational age[2]. Pre-term infants were omitted from the following growth analyses.

[2] See William's criteria in Chapter Four (6).

A striking finding is that deceleration of linear growth starts early in life, declining as early as three to four months. Linear growth is affected much more than weight (see Figures 5.3 and 5.4). The incremental linear growth rates for infant boys and girls is at the 3rd to 5th percentiles, in contrast to weight gain which is at the 15th percentile.

In the six month old infant, z-scores for length and weight have substantially decreased to -1.8±1.0 ($\bar{x}$ ± SD) and -0.7±1.1 respectively (see Table 5.2, Figures 5.7 and 5.8). Head circumference, 50th percentile at birth and at 3 months, declines to the 25th percentile by 6 months of age, paralleling length (see Figures 5.17 and 5.18).

In the 18 to 30 month cohort, stunting is fully established. Wasting is not seen, as evidenced by a mean weight/height z-scores of -0.20. However, for length the mean z-score is -2.1±0.9 (SD) and lower than for weight, -1.6±0.9 (SD). Attained size by month for the toddlers is illustrated in Figures 5.9 - 5.12. The incremental linear growth rates from 18 to 24 months and 24 to 30 months are 5th and 25th percentile in boys and 10th and 20th percentile in girls. Incremental weight gains for both boys and girls are at or just below the median reference value (see Figures 5.13 - 5.16). Incremental head circumference growth has slowed from the 15th to the 8th percentile by 30 months (see Figures 5.17 and 5.18). Whereas the linear growth was better for the infant girls, as toddlers their growth lags behind the boys. At 30 months a slight improvement is seen in mean z-scores for length in both girls and boys (see Table 5.2).

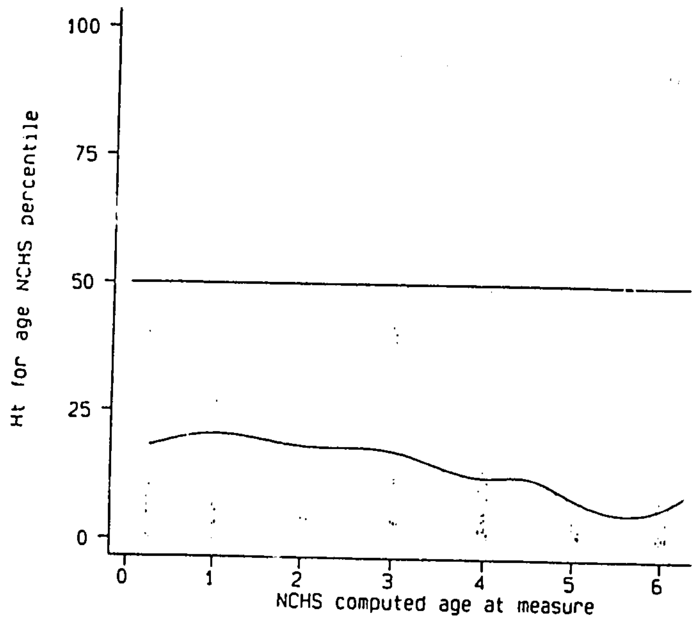


FIG 5.3 Mean infant length for age: Smooth percentile curves using NCHS reference

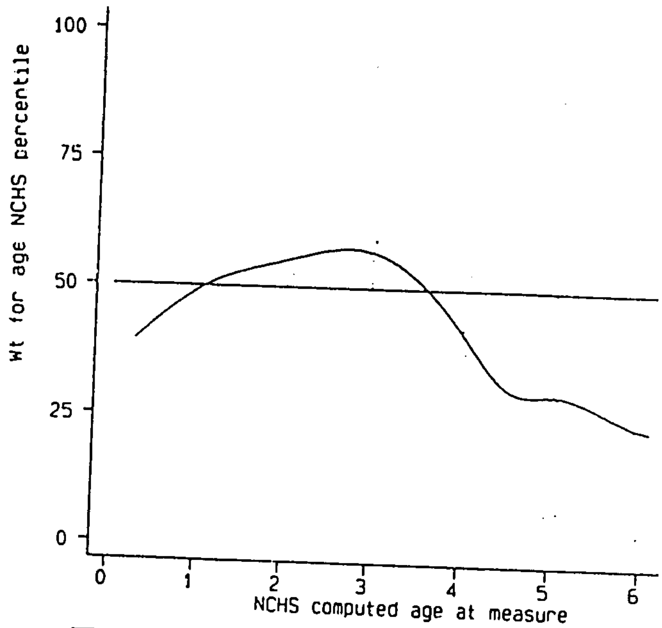


FIG 5.4 Mean infant weight for age: Smooth percenti curves using NCHS reference

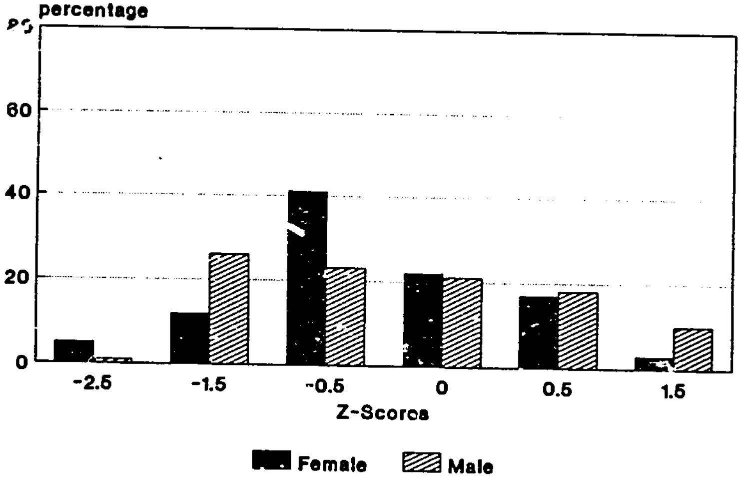


Fig. 5.5: Grouped Z-scores for infant length at birth, by sex

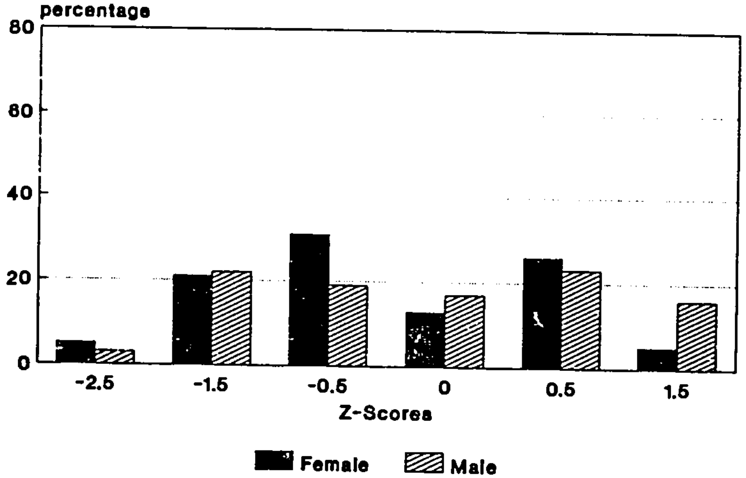


Fig. 5.7: Grouped Z-scores for infant weight at birth, by sex

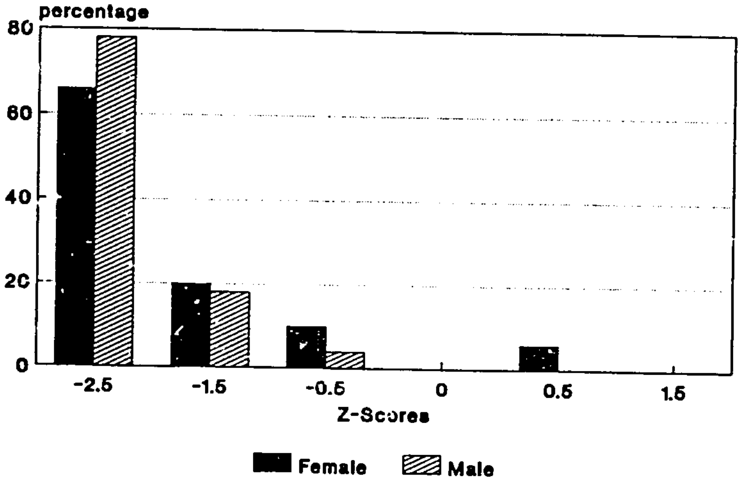


Fig. 5.6: Grouped Z-scores for infant length at 6 months, by sex

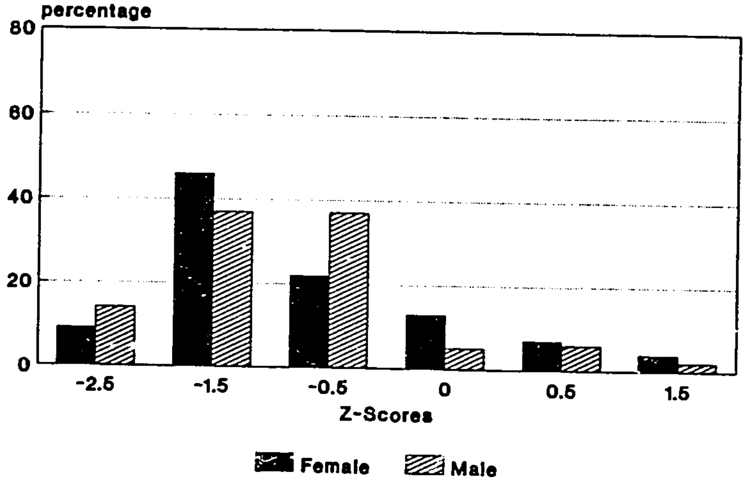
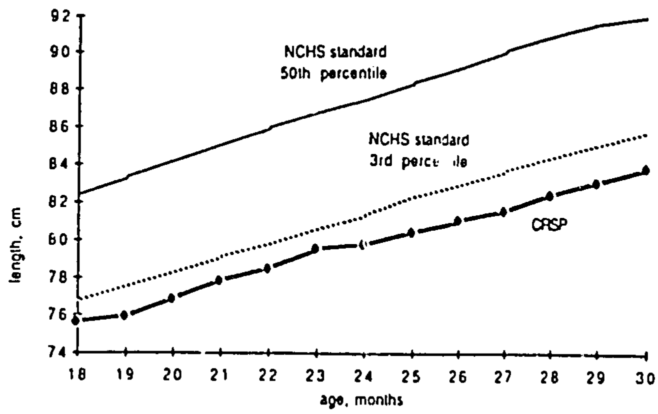
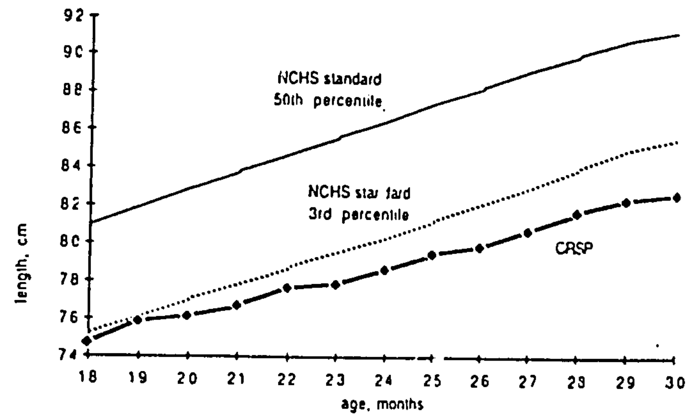


Fig. 5.8: Grouped Z-scores for infant weight at 6 months, by sex



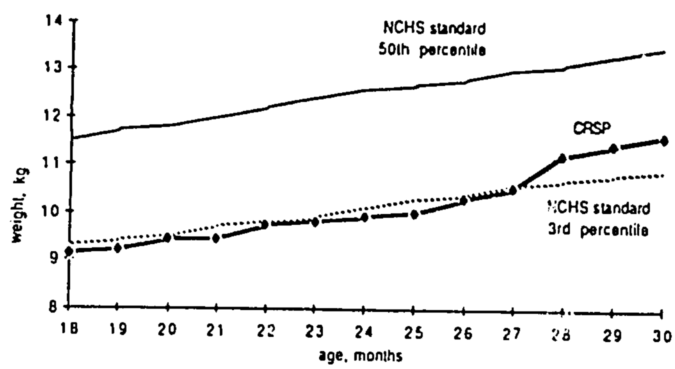
Comparison of male toddlers' mean length by month of age with NCHS standard. (NCHS standard has been adjusted to reflect recumbent length through 30 months; CRSP data is recumbent length)

FIG 5.9



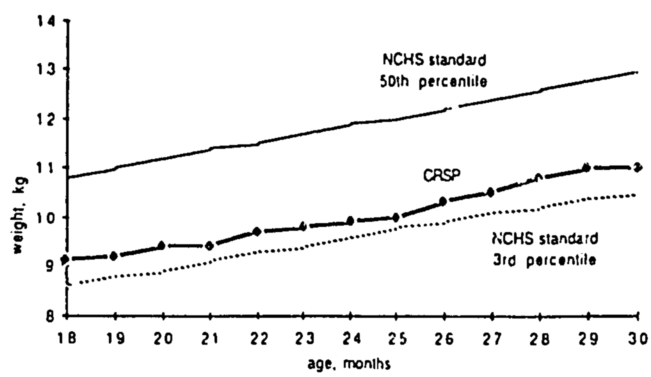
Comparison of female toddlers' mean length by month of age with NCHS standard. (NCHS standard has been adjusted to reflect recumbent length through 30 months; CRSP data is recumbent length)

FIG 5.10



Comparison of male toddlers' mean weight by month of age with NCHS standard

FIG 5.11



Comparison of female toddlers' mean weight by month of age with NCHS standard

FIG 5.12

Incremental growth rates (NCHS) for infant and toddler girls and boys for length, weight and head circumference

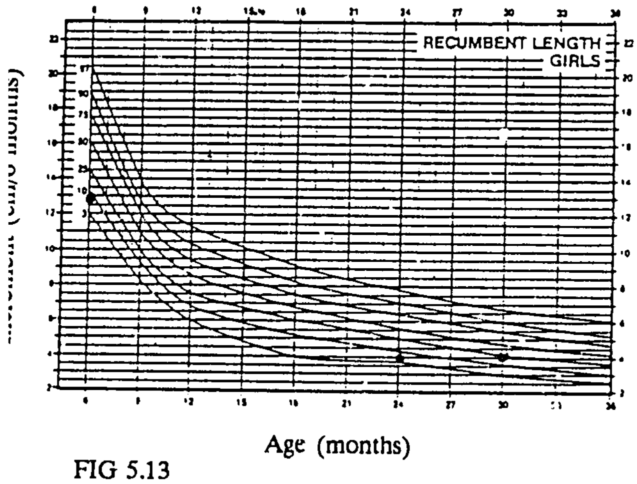


FIG 5.13

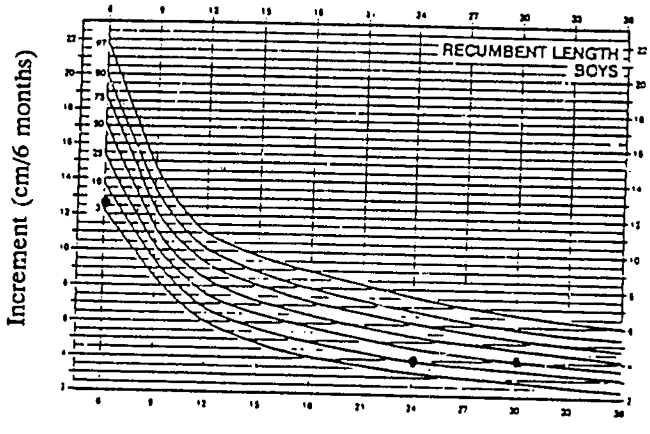


FIG 5.14

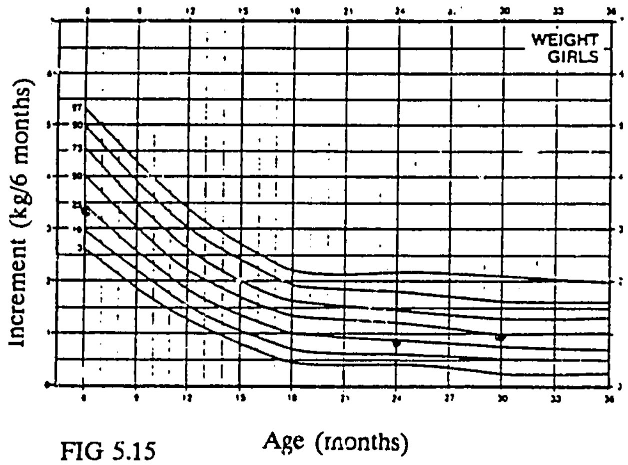


FIG 5.15

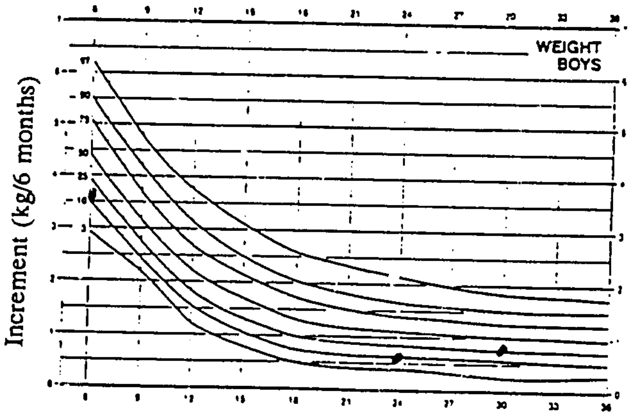


FIG 5.16

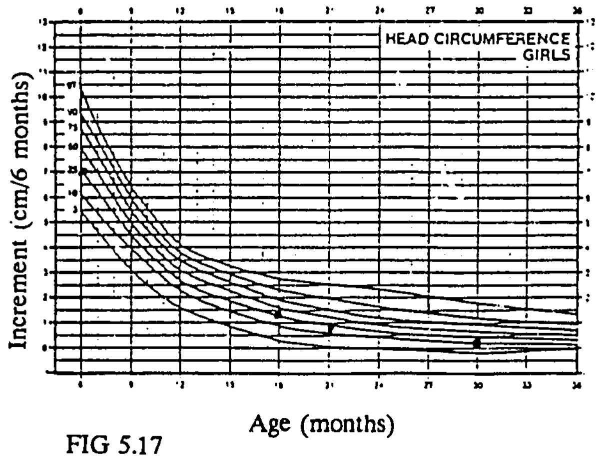


FIG 5.17

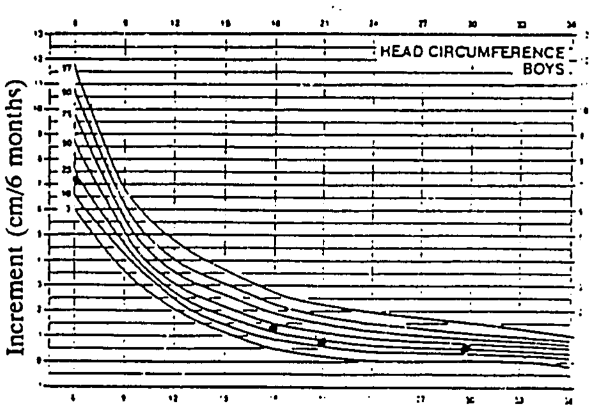


FIG 5.18

Incremental growth rates (NCHS) for schooler girls and boys for height and weight

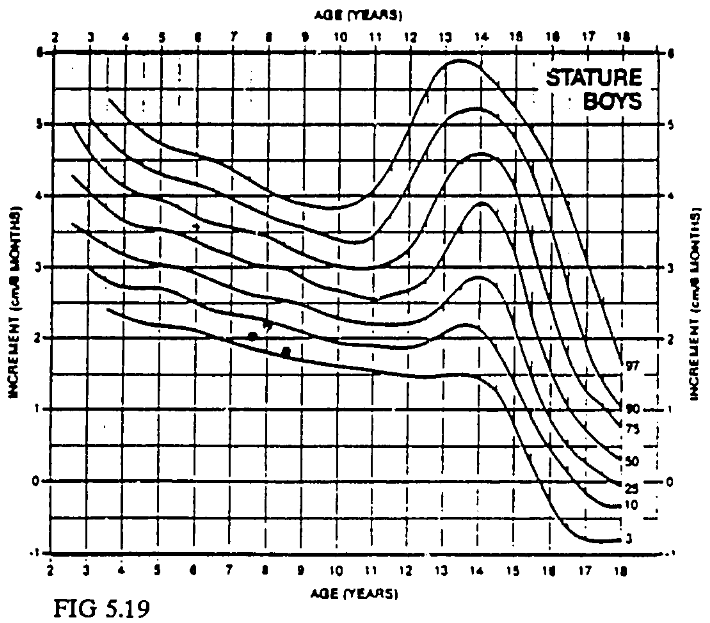


FIG 5.19

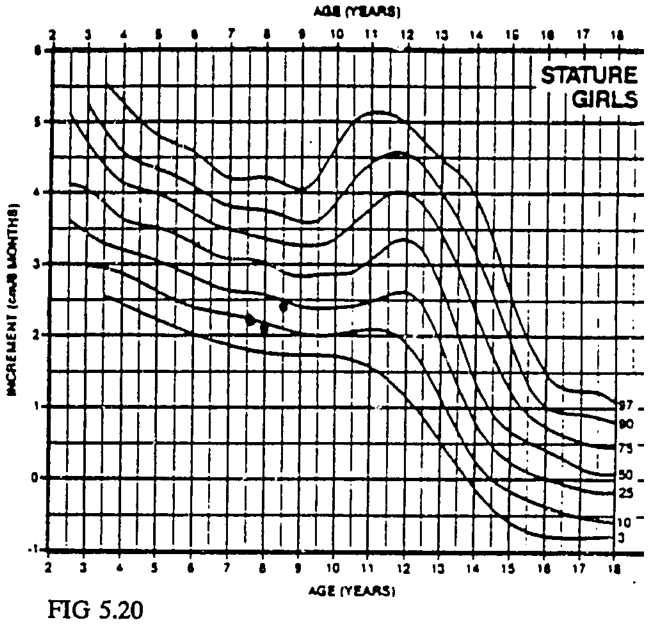


FIG 5.20

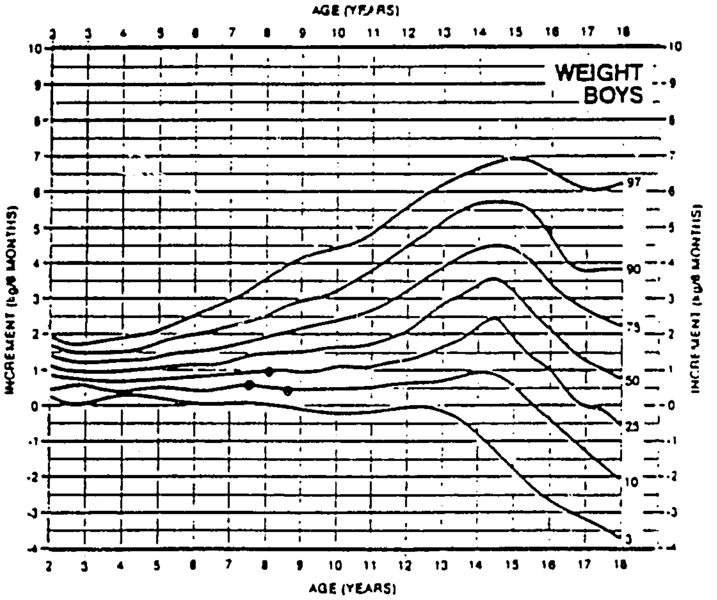


FIG 5.21

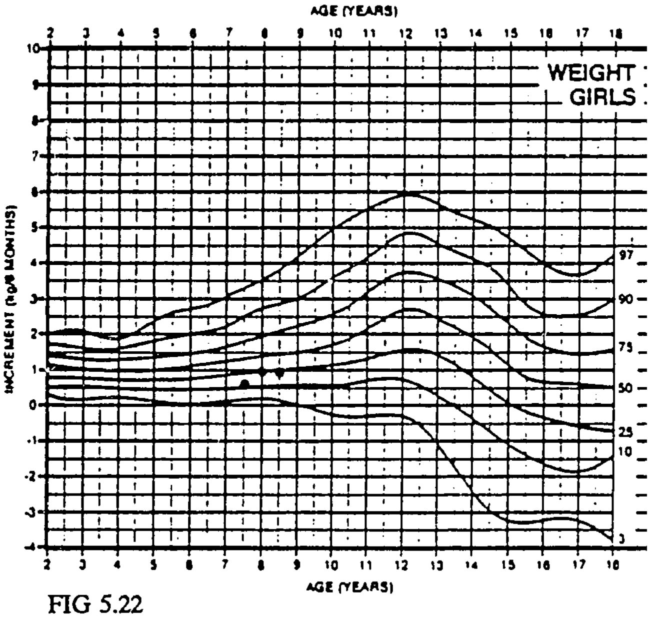
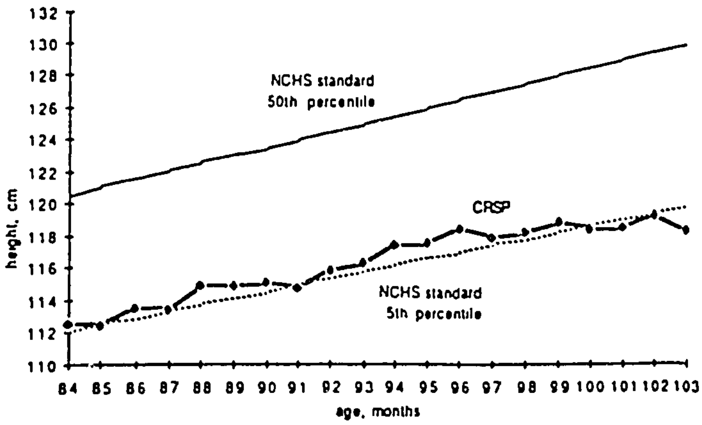
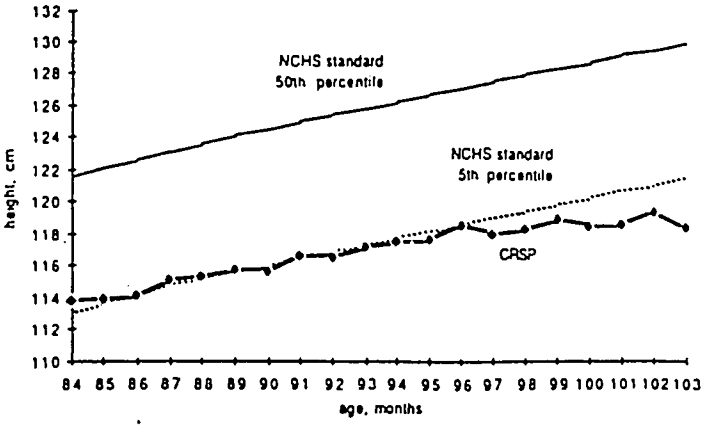


FIG 5.22



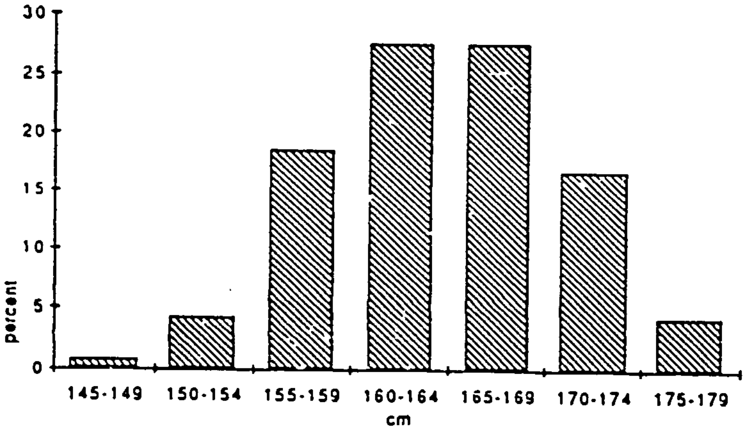
Comparison of female schoolers' mean height by month of age with NCHS standard.

FIG 5.23



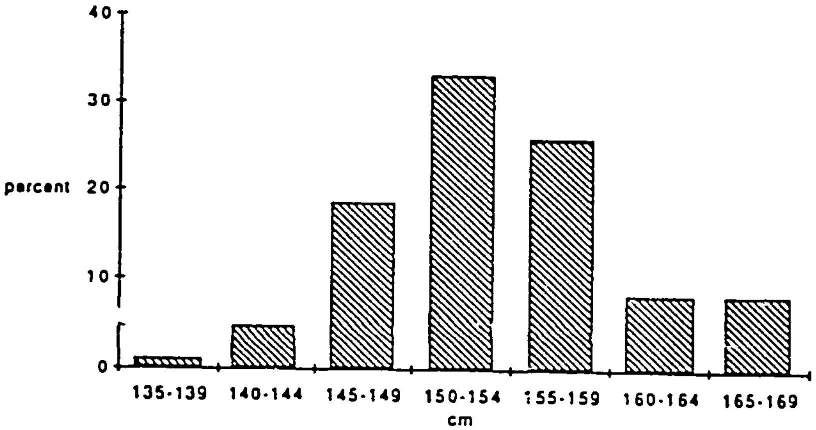
Comparison of male schoolers' mean height by month of age with NCHS standard

FIG 5.24



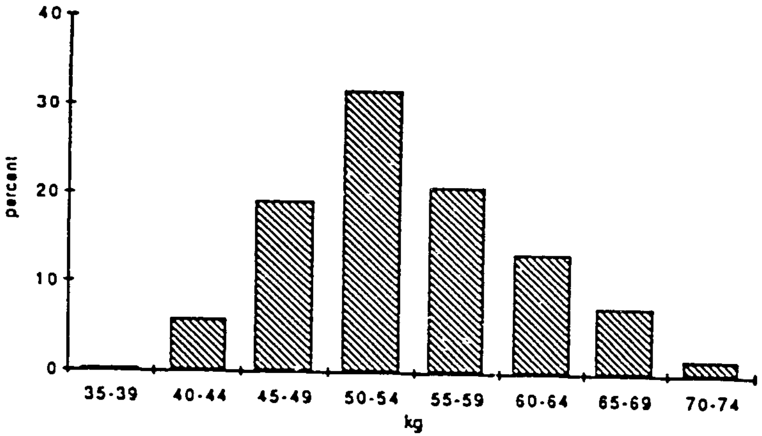
Distribution of lead male heights in January 1984 (n=120).

FIG 5.25



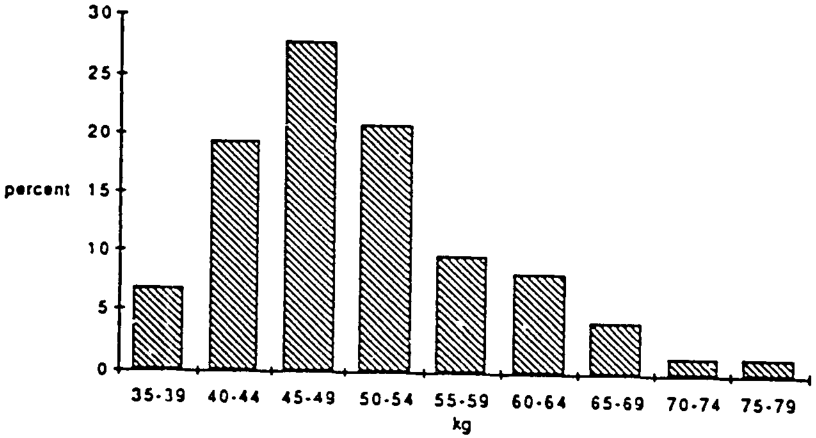
Distribution of non-pregnant, non-lactating lead female heights in January 1984 (n = 108).

FIG 5.26



Distribution of lead male body weights in January 1984 (n = 120).

FIG 5.27



Distribution of non-pregnant, non-lactating lead female body weights in January 1984 (n = 72).

FIG 5.28

By school age, between ages 7 to 9 years, no appreciable catchup growth is seen for height. Schoolers remain at mean z-scores of -1.8 for height/age and -1.6 for weight/age (see Table 5.2). Incremental growth is generally at the 3rd percentile for the boys but increases to the 10th to 25th percentile for the girls (see Figures 5.19 - 5.24).

In the 12 to 14 year age group (former schoolers), z-scores, particularly for height, show a slight decline to -1.9 for both males and females. Z-scores for weight/age decline in comparison to those of the schooler age groups. (see Table 5.2 and Figures 5.1 and 5.2).

In the 12 to 17 year old non CRSP sample of non menarcheal girls, mean height and weight in year by year age groups are below the 5th percentile. Between the ages of 16 to 18 years a slight improvement is seen with values increasing to the 10th percentiles. In the menarcheal group, using adult weight/height reference levels (5) all age groups are below the reference median. For girls between 15 to 18 years of age the mean wt/ht value is at the 20th percentile. In the menarcheal group, girls attained the CRSP sample adult mean height of 154.2 cm and adult mean weight of 50.2 kg by 16 to 18 years of age. These findings are in agreement with Kulin (7) who found onset of puberty at 15 to 16 years with late linear growth in a group of moderately malnourished rural Kenyan teenage girls.

By *adulthood*, mothers and fathers have similar and slightly improved z-scores for height compared to the adolescent. However in regard to weight, the men show much lower z-scores than women, and have lower body mass indices. Despite attempts at late catch-up growth in height, at least in the adult women, the adults still remain at -1.5 z-scores for height. There is some variability in adult size with up to 10% of women being taller than the median for height and 8% being heavier than the median for weight (see Table 5.3, Figures 5.25 - 5.28).

TABLE 5.3.
Percent of sample at or above NCHS median value for stature and weight

		Stature %	Weight %
Infants	newborn	18	36
	6 mos	3	23
Toddler	18 mos	2	3
	30 mos	4	4
Schooler	84 mos	6	6
Adults	Women	10	8
	Men	5	<1

DETERMINANTS OF INFANTS GROWTH

In an attempt to understand why growth failure develops so early in life, it is important to examine the mother's size, body composition and food intake during pre-pregnancy, pregnancy and lactation and also the infants's size at birth and feeding history.

Maternal Nutritional Factors During Pregnancy and Lactation

In exploring the hypothesis that maternal food intake affects her infant's growth early in life, pre-pregnancy, pregnancy and lactation factors are examined in relation to the infant's attained growth and rate of growth from 0 to 6 months of age. These factors include: maternal food intake during pregnancy and lactation with consideration of quantity and quality of the diet; maternal size upon entry into pregnancy; weight and fat changes throughout pregnancy and lactation, including net postpartum pregnancy fat and weight change; infant's birth size and gestational age; and supplemental feeding. Non-nutritional factors include infant morbidity, family SES, parental literacy and family size and composition. Infant growth is considered a reproductive outcome, and although breast milk production and intake were not measured directly, infant growth reflects lactation performance.

Food Intake and Infant Growth

Pregnancy

Maternal mean daily intake of total kcals, protein and fat throughout pregnancy were found to be positively associated with both infant weight and length. Correlations are strongest for fat intake, a concentrated source of energy. No association was found with the rate of infant weight gain (slope) in relation to pregnancy intake. The volume, fat content and energy composition of the breast milk are not known, except for crematocrit determinations which are difficult to interpret.

TABLE 5.4.
Relation between macronutrient intake in pregnancy and lactation on attained sizes in infants zero to six months

	Length (n=110-120)		Weight (n=110-120)	
Pre-pregnancy	r*		r	
kcal	.34		.30†	
protein	.32		.38	
Trimester 2				
kcal	.16 - .36		.18 - .24	
protein	.22 - .29		.19 - .23	
fat	.20 - .31		.20 - .23	
Lactation	Length 0 to 6 mos	Slope	Wt 0 to 6 mos	Slope
kcal	.19 - .28	-.24	.18 - .27	NS
protein	.20 - .26	-.20	.22 - .25	NS
fat	.24 - .28	-.19	.18 - .31	.22

* Pearson's correlations, 2 tailed, p <.05 all correlations presented are statistically significant (p<.05 - .001)
† Six month weight and length only; all others are monthly values from 0 to 6 months.

Lactation

Maternal energy intake during lactation relates positively to infant attained length and weight from ages 2 to 5 months. Pearson's correlations are significant and range from r=.23 to .27, p<.05, (n=120). Fat intake in lactation correlates even more strongly than does kcal intake. However, the rate of linear growth relates negatively to lactation food intake. One explanation may be that the larger women eat proportionately more food and have the larger infants. These infants grow at a slower rate than the smaller, infants who attempt to "catch-up" in their growth. This more rapid rate of growth of smaller, slightly less mature infants is demonstrated below (see in Predictors of Infant Size).

The Role of Diet Quality and Micronutrients on Infant Growth

It is assumed that micronutrient and vitamin levels in breast milk reflect maternal dietary intake and storage of these nutrients. A concern in the Embu women is that low B_{12}, iodine, folic acid and zinc intakes, plus poor zinc bioavailability will have adverse effects on infant growth, mediated through breast milk deficient in some of these nutrients. The infant is dependent largely on breast milk and to a much lesser extent on supplementary feedings. Information on iodine deficiency in mothers during pregnancy and lactation and findings of low B_{12} levels in breast milk are presented in the Food Intake and Reproductive Function chapters.

In regard to *zinc* nutrition, serum levels were measured in a very small subsample of nine lactating women and found to be low in three of these women. The zinc content of the infant supplemental foods, although of poor bioavailability, does supply a mean of 6.7 ± 0.5 ($\bar{x}$ ± SD) mg of zinc per day. Maternal zinc intake during lactation did not relate to infant growth. Bioavailable zinc, e.g. using zinc/phytate molar ratios, and taking other diet factors into account, has yet to be used in this analysis.

In contrast to zinc, the relationship between maternal *vitamin B_{12}* intake during pregnancy and lactation and infant growth is positive and statistically significant. In preliminary analyses, partial correlations remain significant both for infant attained size and rate of growth, even when controlling for maternal mean kcal intake (see Table 5.5). Further analyses must control for other nutrients related to growth (i.e. zinc, protein, etc.). The relationship between low breast milk B_{12} content and infant growth has not yet been analyzed. The supplemental foods supply a mean of 0.21 ± 0.26 (SD) μg/day of B_{12}. However the exact level of B_{12} in the various fermented cereals used is highly variable.

TABLE 5.5.
Correlations between infant weight and length at 3 and 6 months of age with maternal vitamin B_{12} intake during lactation

		B_{12} Intake			
	n	r*	p	r†	p
Infant weight	119				
at age 3 mos		.20	.03	NS	
at age 6 mos		.27	.003	.31	.003
weight gain rate at 0-6 mos		.20	.03	.26	.01
Infant length	119				
at age 3 mos		.21	.03	NS	
at age 6 mos		.28	.002	.28	.006
length gain rate at 0-6 mos				.23	.02

* r: Pearson's (2-tailed) $p<.05$
† r: partial correlations controlling for kcal intake

Iodine deficiency was found to play a role in reproductive outcomes, both newborn and maternal (see Chapter Four). Several parameters of iodine deficiency are related positively and significantly to infant growth in the first six months of life. Partial correlations were obtained after controlling for SES, since SES is also positively associated with infant growth and with household use of iodized salt.

Iodized salt use by the household and the thyroid hormone FT4 are each positively associated with the infant's weight/age, length/age and mean upper arm circumference (MUAC) from three to six months of age. Non iodized salt use is negatively associated with infant weight in 5 month old infants. As for TSH, the higher the level, the less the infant's weight and MUAC in the 6th month (see Table 5.6).

TABLE 5.6.
Maternal thyroid size, iodized salt use, thyroid hormones and infant size 0 to 6 months controlling for socioeconomic status

		n	Partial correlations	p
Thyroid Size	vs. Weight at 6 mos.	96	.19	.06
	vs. Length at 6 mos.	96	.22	.04
Iodized salt use	vs. Length at 5 mos.	64	.26	.04
Non iodized salt	vs. Infant weight at 5 mos.	41	-.24	.05
Thyroid hormones				
TSH	vs. Weight at 6 mos.	28	-.37	.06
	MUAC at 6 mos.	28	-.43	.02
T4	vs. Weight at 5 mos.	28	.38	.05
FT4	vs. MUAC at 3 mos.	28	.39	.02
	at 6 mos.	28	.47	.005

Relation between Maternal Size and Infant Growth

The mother's size upon entry into pregnancy determines, in large measure, the child's growth and attained size. Maternal height, pre-pregnancy weight and weights in all trimesters and in lactation and weight and fat changes all consistently and positively correlate with infant size. Weight, length, head circumference and fat stores are included as measures of infant size (see Table 5.7).

TABLE 5.7.
Summary of correlations* between maternal size and infant size from 0 to six months

INFANT:	Weight	Length	MUAC
Maternal size			
Weight			
Pre-pregnancy, pregnancy and lactation	Sig† pos	Sig pos	Sig pos
Height	Sig pos	Sig pos	NS
BMI			
Pregnancy and lactation	Sig pos	Sig pos	Sig pos
Head Circumference	Sig pos	Sig pos	NS
MUAC			
Pre-pregnancy, pregnancy and lactation	Sig pos	Sig pos	Sig pos

* Pearson's correlations (2-tailed: $p<.05$)
† Statistically significant. $p<.05$-$.0001$

In estimating the contribution of parental size to infant size at six months of age, using regression analysis, maternal and parental weight and height were found to account for 14% and 17% of the variance in the infant weight and length, respectively. A shared environment and/or genetic factors are probably operative here.

Maternal Fat Stores and Infant Growth

All parameters of maternal fat stores (i.e. sum of fat folds, percent body fat, MUAC) in pregnancy and lactation relate positively to the rate of infant weight gain, attained weight and attained length (see Table 5.8). This is particularly true for infant fat folds during the first six months of life. The strongest relationships with infant size are found with maternal thigh and subscapular fat folds during lactation. These fat folds change the most in the course of pregnancy and lactation. Triceps fat folds change the least and may not be the best site for estimation of energy reserves in reproduction. Correlations between thigh fat folds for infant height are .30 - .37 ($p<.001$) and for weight .30 - .39 ($p<.001$) versus triceps which give correlations in the range of .25 - .27, $p<.01$.

TABLE 5.8.
Summary of correlations* between maternal fat stores (sum 6 fat folds, MUAC) and infant size from 0 to six months

INFANT:	Weight	Length	MUAC
Maternal Fat Stores			
Fat folds (sum 6) Pregnancy	Sig pos	Sig pos	Sig pos
Lactation	Sig pos	Sig pos	Sig pos
MUAC			
Pregnancy	Sig pos	Sig pos	Sig pos
Lactation	Sig pos	Sig pos	Sig pos†

* Pearson's correlations (2-tailed: $p<.05$)
† For months one to four years of age

A negative relationship between MUAC change in pregnancy and subsequent infant growth in length and weight from 0 to 6 months was seen. Those mothers who had the largest decrease in fat folds and MUAC during pregnancy had infants who gained the least weight, fat and length from 0 to 6 months of age (see Table 5.9). During lactation a gain in MUAC in the mother was associated with the longer and heavier infants.

TABLE 5.9.
Relationship between change in MUAC in pregnancy and infant size from 0 to 6 months of age

		Range in correlation from 0 to 6 mos r*	p
Change in MUAC during pregnancy (represents loss of fat)	vs. Weight	-.22 to -.37	.05 to .002
	Length	-.40 to -.46	.03 to .008
	MUAC	-.20 to -.40	.05 to .001
Change in MUAC during lactation (gain)	vs. Weight	.15 to .26	.02 to .10
	Length	NS	
(loss 0-5 mos)	MUAC	-.20 to -.24	.04 to .05
(gain 4-6 mos)	MUAC	.20 to .21	.05

* Pearson's correlations (2-tailed $p<.05$).

Thus it is seen, that maternal fat stores in the pre-pregnancy period, maternal fat deposition in pregnancy and the ability to draw on fat stores for energy during lactation contribute to the success of lactation and support of infant postnatal growth. This is most likely mediated through the positive effects on lactation, either the quantity and/or composition of the breast milk.

Role of Supplemental Feeding in Infant Growth and Morbidity

By three months of age, 90% of infants are receiving supplemental feedings. This raises concerns at two levels: the displacement of breast milk by less nutritious food than breast milk and increased incidence of diarrheal and other infectious illness. Increased illness may occur due to contaminated feedings and loss of the anti-infectious properties of human milk. Commercial formula is generally not used and the supplemental foods consist of home preparations using cow's milk and maize or millet gruels which are occasionally fermented. These supplemental foods may supply small amounts of zinc and B_{12}.

Analysis of the impact of supplemental feeding on the infant shows a weak but statistically significant negative effect on the rate of weight gain, attained length and linear growth. A slight increase in febrile, but not in diarrheal illness is also seen.

Despite the use of supplemental feeding, the mothers continue to breast feed their infants on demand day and night for a mean duration of 17 months. Although breast milk intake was not measured, no differences were noted in the duration and frequency of breast feeding in supplemented or non-supplemented infants between the ages of 4 to 6 months, a time when the energy content of such feedings increases to a mean of 258 $\pm$ 114 ($\bar{x} \pm SD$) kcal/day and 3.3 g of protein/day. The mothers' main reasons for supplementing their infants are perceptions that the infants appear hungry and are no longer satisfied by their breast milk alone.

Infant Morbidity

Morbidity has a negative effect on infant growth. The proportion of days ill in the first 6 months of life negatively affects weight gain and linear growth. Diarrhea incidence is low in the early months but increases in the infant from four to six months. Febrile episodes, including clinical malaria, have strong negative effects on attained length and rate of linear growth, particularly in the first 3 months of life. Severe illnesses, mainly high fever and lower respiratory illness, correlate negatively with the rate of weight gain and with infant fat stores (see Table 5.10).

TABLE 5.10.
Relation of infant illness to attained size and rate of growth from 0 to 6 months

Growth Measure	n	Illness Measure	r*
	120	% days of:	
Weight		Fever	-.21
		Respiratory illness	-.18
Weight slope		Severe illness	-.25
Length		Malaria (clinical)	-.28
Sum 3 fat folds		Severe illness	-.26

* Pearson's correlations - 2-tailed, all correlations are significant <.001 to <.05.

Predictors of Infant Size

To determine which variables best predict infant size and rate of growth, a set of multiple regression analyses were carried out using the "best sub-set" approach (8) (see Table 5.11).

For attained infant weight and length at six months of age, birth weight was the strongest predictor, followed by maternal pregnancy weight and fat gain, lactation weight gain and SES. Energy intake from infant supplemental feeding in the first three months had a negative impact on the infant's length and rate of weight gain. The above variables account for 27% of the variance in weight and for 41% in height for age.

In regard to the rate of linear growth, the less mature and smaller the infant (lower GA) the more rapid the rate of linear growth. Maternal fat gain in pregnancy and lactation and maternal kcal intake in lactation promote the rate of linear growth. This is most likely due to the positive effect of energy intake on milk production, although this was not directly measured. The above factors account for 15% of the variance in weight gain and 24% of the variance in rate of linear growth (see Table 5.11).

TABLE 5.11.
Multiple regression (best subset) analyses variables for infant size and rate of growth from zero to six months

	Attained Size		Rate of Growth (slope)	
Outcomes	Weight	Length	Weight	Length
No. of cases	69	68	75	75
Variables selected to enter regression equation	BW[1]	BW		Gest age (neg) MFG preg
	MWG[2] preg	MFG[3] preg		
	MWG lact	MWG lact	MWG lact	
	SES		SES	
			Mat kcal intake (lact)	Mat kcal intake (lact)
		infant supplem (neg)	infant supplem (neg)	
R^2	0.27	0.41	0.15	0.24
F	5.8	11.1	4.2	3.6
p	0.0005	0.001	0.01	0.005

1 BW:birth weight. 2 MWG:maternal weight gain. 3 MFG:maternal fat gain.

Summary

The strongest determinants of infant growth from zero to six months are maternal size and food intake, both quantity and quality, in pregnancy and lactation. Inadequate energy intake during pregnancy with poor weight gain and fat storage is poor preparation for lactation. Although energy intake increases to pre-pregnancy levels it is still not sufficient to supply the additional 350 to 500 kcals/day needed for optimal lactation and the mother's own needs. Deficient intake of micronutrients and vitamins, which affect the quality of breast milk, at least in regard to vitamin B_{12}, compounds the problem of low energy intake. Low maternal B^{12} intake was associated with poor infant growth when controlling for kcals. Early infant supplementation, an age-old practice in Embu, has a slight negative affect on growth, even thought the food may contain small amounts of zinc and B_{12}. Infant morbidity also contributes to early growth faltering.

Solely breast fed infants in the USA have been observed by Dewey et al (9) to gain weight at a slower rate than infants who are partially breast fed or formula fed. This decline at three to four months is considered normal and not taken into account by the NCHS reference curves. On the other hand, linear growth rates did not decline in the exclusively breast fed infants in the USA study. Clearly length is far more affected than weight in the Kenyan infants. Not only may the quantity and quality of Embu women's breast milk be inadequate, but the infants with intrauterine retardation of linear growth may show poor catch-up growth.

DETERMINANTS OF TODDLERS GROWTH

The toddler, upon entry into the study cohort at 18 months of age, is already stunted. Weight for age is reduced but to a lesser extent than length, and weight for length is near the median reference value. Because of the study design, children were not observed between six and 18 months, and the previous food intake, morbidity and growth pattern of the 18 month old child were not known. However, parental size and family and household factors were known and could then be related to the attained size of the child.

Factors Associated with Size at 18 Months

The principal factors associated with toddler length at 18 months derived from a multiple regression analysis are parental height, sex of the child and socioeconomic status of the household. Together these variables account for 20% of the variance in toddler length at 18 months (see Table 5.12). Other variables not entering the equation, but none the less significant, are the number of children under six years old in the household, which has a negative effect, and the birth date or seasonality. Seasonality is a reflection of the age of the child when it passed through the food shortage period. The shortage coincided with the cold season, a period of increased incidence of respiratory infections. The younger the child during the food shortage period, the better the linear growth as the younger toddler may have been protected by partial breast feeding or preferential feeding. The findings for weight of the child at 18 months are very similar to those for length.

TABLE 5.12.
Multiple regression (best sub-set) analyses for toddler length at 18 months.

Variables included in "best subset"	Standard regression coefficient	p	Contribution to R^2	Other significant variables not entering equation
Sex	-.17*	.08	.03	Height
SES	.26	.008	.07	Child's intake: fat, protein
Maternal height	.20	.038	.04	Parental literacy
Paternal height	.24	.014	.06	No. children <6 yrs

n=93 cases; F=5.58; R^2=.20; p>F .0005
* Sex 1=male, 2=female

The toddler, now stunted, grows within the normal range for linear incremental growth between 18 to 24 months albeit at the 6th and 10th percentiles for girls and boys respectively. Over the next six months, the incremental growth rate increases to the 30th percentile for boys and the 20th percentile for girls, reflected in very slight improvement in the z-score for length at 30 months. (See Table 5.3, Figures 5.12, 5.13 - 5.16). For incremental weight, the boys gain at or slightly above the reference median values and the girls at or somewhat below the reference median values.

Predictors of Attained Growth at 30 months

Food Intake

The toddler diet, low in energy, micronutrients, vitamins and calcium is described in the Chapter Two. All food intake variables; kcal intake and particularly fat, animal protein and iron; from 18 to 30 months relate positively to the toddler's attained length and weight at 30 months and the rate of linear growth and weight gain from 18 to 30 months (see Table 5.13). A multiple regression analysis for length at 30 months, using four macronutrients (kcal, fat, carbohydrate, protein) and animal protein and controlling for weight at 18 months, indicates that 31% of the variance in length is accounted for by food intake. Maternal diet quality, i.e. fat intake, animal protein and iron relate positively to toddler linear growth and weight gain (see Table 5.13).

TABLE 5.13.
Relation between child's food intake and maternal intake and child's size at 30 months (n=98 to 111).

	Length		Weight
	attained	slope	attained
	r*	r	r
Child's Intake			
kcal/d	.30	.19	.29
fat g/d	.37	.27	.21
Total protein g/d	.20	.16†	.20
Animal protein	.35	.16†	NS
Carbohydrate g/d	.25	NS	.27
Maternal Intake			
kcal/d	.36	.32	.29
fat g/d	.35	.31	.31
iron mg/d	.27	.32	.25

* Pearson's correlation (2-tailed), all are statistically significant $p<.05$ -.001
† $r=.16$, $p<.10$ (borderline)

An analysis of food patterns and growth in toddlers and schoolers carried out by Murphy, Calloway and Lien[3] is particularly useful for developing future interventions. Intake of foods with high carbohydrate content and particularly fat, sugar and animal source foods were significantly associated with attained length and weight at 30 months and with the slope of linear growth. Maize was negatively correlated with growth (see Table 5.14).

Using a factor analysis, two main food groups were identified. The first included milk, cereal grains, fat, potatoes and sugar and correlated positively and significantly with attained length and weight at 30 months and with the slope of linear growth ($r=.49$, $p<.01$). This group of foods was associated with high SES. The second group included maize, sorghum, green leafy vegetables and beans. The maize component, was negatively associated with length. This latter group has high phytate and fiber content, which reduces bioavailability of iron and zinc (see Table 5.15). The negative association of maize, millet and phytate with length may represent the inability of a poor household to afford animal protein foods, rice and sugar and heavy reliance on the maize staple.

[3] Investigators at University of California, Berkeley. (unpublished data).

TABLE 5.14.
Food type predictors of toddler and schooler size: attained (attd) size and slope of growth*

	TODDLERS				SCHOOLERS			
	Length Attd	Length Slope	Weight Attd	Weight Slope	Height Attd	Height slope	Weight Attd	Weight slope
Pattern I	r†	r	r	r	r	r	r	r
Veg. fat	.40	.34	.25		.19	.30	.22	.16
Sugar	.40		.28			.22		
Potato	.25	.18		.30		.27	.17	
Wheat	.18	.17	.20					
Rice				.21	.24	.14	.20	
Milk	.23	.18			.24	.32	.16	
Maize		-.24				-.16	.30	
Pattern I factor‡	.49	.27	.27	.20	.18	.32	.16	.14
Pattern II								
Green Veg		-.18						
Maize		-.24				-.16	.30	
Meat/poultry	.30		.24			.20	.19	.15
Tea			.21	.25				
Fruit/veg					.14			
Beans						.37	.28	.21
Pattern II factor	.17	-.24	.21	.17		.18		

* Based on analyses by Murphy S, Calloway D and Lien D. University of California, Berkeley.
† Pearson's correlations (2-tailed) only correlations shown, $p<.10$
‡ Factor analyses

Zinc

Toddler zinc intake was examined in relation to toddler height and weight. The predicted prevalence of inadequate intake of zinc for Embu toddlers is estimated to be at 97% for the normative requirement and 75% for the basal requirement (10). Zinc, because of its role in stunting, was examined in relation to attained toddler height and weight at 30 months of age. Because of the low bioavailability of zinc, due to foods high in fiber and phytate and low in animal heme protein, a new variable of bioavailable zinc was created based on the dietary content and the above components[4] (10).

Zinc intake (not modified for bioavailability) from 18 to 30 months did not correlate with the toddler's weight or height. However, after controlling for kcal intake, phytate and fiber showed significantly negative associations with the toddler's weight and length at 30 months. Bioavailable zinc intake at 24 and 30 months yielded significant and positive correlations with 30 month length. However, when controlling for kcal intake the partial correlations were no longer significant (see Table 5.15). In addition, other factors such as parental height, SES and iodine should also be controlled for. The algorithm for bioavailable zinc contains animal protein and kcal.

TABLE 5.15.
Toddler attained length at 30 months in relation to zinc, phytate, fiber intake and bioavailable zinc intake (controlling for kcal intake)

	Height		Height (controlling for kcal/d)	
	r*	p	r	p
Zinc	.10	NS	-.12	NS
Available zinc	.25	.01	.10	NS
Phytate	-.17	NS	-.28	.02
Fiber	-.15	NS	-.25	.03

* Pearson's correlation: (2-tailed) p<.05

Parental Size

Both maternal and paternal size correlate strongly with the child's length and weight at 30 months. Regression of the mother's height and the father's height on the child's 30 month length yields R^2=.31, p<.01 for maternal height and R^2=.05, p<.05 for father's height

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[4] Algorithm for bioavailable zinc, Murphy, Calloway, Lien. University of California, Berkeley.

respectively. Thus, a third of the variance in length at 30 months is explained by maternal height.

Child's Initial Size

The child's own size at 18 months determines its rate of the growth. As seen with the infants, the smaller the toddler in regard to its 18 month length, the steeper is the slope of linear growth. This attempt at catch-up growth is no doubt restrained by the quantity and quality of the diet and other environmental factors.

Morbidity

Acute infectious illness, especially severe illness and diarrheal disease, have a negative impact on the growth of the toddlers as on the infants, with linear growth affected more than weight (see Table 5.16). As was shown in the chapter on Morbidity, food intake is decreased significantly in the presence of common acute infectious illness. Given the high incidence of acute infectious and febrile illnesses, this loss of energy intake can be considerable. Also it has been well established in numerous studies that acute infectious disease especially in young children, has a catabolic effect (1).

Anemia (Hb<10 gm/dl) was found to adversely affect linear growth and weight gain. Iron intake per se was associated with decreased growth in length, the effect perhaps mediated through anorexia, a prominent symptom in children with iron deficiency anemia (10).

TABLE 5.16.
Relation between severe illness* from 18 to 30 months and toddler 30 month attained size and slope of growth (n=98-111)

	LENGTH		WEIGHT	
	Attained r†	Slope r	Attained r	Slope r
Severe Illness (18-30 months)	-.21	-.19	-.16‡	
Anemia (<10 g Hb/dl)		-.28		-.18

* Days of severe illness per person months observed
† Pearson's correlation (2-tailed, p<.05 -.01)
‡ r=.16, p<.10 (borderline)

Family and Household Characteristics

Socioeconomic status, household sanitation scores and level of parental literacy are all associated with length and weight of the 30 month old child. SES was shown to correlate strongly with intake of foods which support growth, such as fat and animal protein. Better household sanitation and parental literacy are associated with fewer infectious illnesses.

Household composition is as important as the actual number of people residing in a household. The greater the number of children under 18 months (younger siblings of the toddlers) and the greater the total number of children under 6 years of age in a given household, the shorter the toddlers are at 30 months. This is probably linked to the finding that less total protein, fat and iron is ingested by toddlers 27-30 months and by the mothers as well in such households. Thus, growth and food intake are adversely affected by family size and particularly by the number of young children, as sufficient quantities of food become a problem (see Table 5.17).

TABLE 5.17.
Familial and household factors related to toddler size at 30 months (n=98-110).

	Weight	Length
Household	r*	r
Socioeconomic status	.21	.27
Sanitation	.22	.17
Literacy	.26	.27
Household size		
Number < 6 years		-.18
Number < 18 years		-.16†
Parental size		
Maternal height	.21	.26
Paternal height	.22	.24
Maternal weight	.35	.28

* r= Pearson's correlations (2-tailed, p<.05 -.001)
† r=.16, p<.10 (borderline)

Relative Importance of Factors: Multiple Regression Analyses

To estimate the relative importance of various influences on toddler growth, several multiple regression analyses were carried out for attained length and rate of linear growth (see Table 5.18).

The strongest predictor of 30 month length is the child's length at 18 months. Other factors, in order of decreasing importance, are maternal fat intake, seasonality[5] and the negative effect of household size. As pointed out, the younger toddlers fared better than the older toddlers during the drought, implying that they were more protected than older toddlers.

For the slope of linear growth, maternal fat intake, seasonality, and the child's own fat and iron intake were positive factors and household size and days of diarrhea had negative effects (see Table 5.18).

TABLE 5.18.
Multiple regression (best set) analyses for attained toddler length at 30 months and slope of linear growth from 18 to 30 months.

Variables included in best subset	Standard regression coeff	p	Contrib to R^2	R^2	p	Other significant variables not in equation
Outcome: attained length at 30 mos.						
Length:18 mos.	.87	.000	.71	.84	.0001	Maternal height
Maternal fat intake	.17	.001	.03			SES
Season	.08	.085	.01			Child's protein intake
Household size	-.08	.072	.02			
Outcome: linear slope 18-30 mos.				R^2	p	
Maternal fat intake	.25	.018	.05	.27	.0002	Parental size
Season	.27	.005	.07			Season
Household size	-.14	.124	.07			Maternal fat intake
Child's Intake fat	.38	.025	.04			

[5] Seasons are in Julian calendar days as is the child's birth day. The higher the Julian number the younger the child during the food shortage.

Variables included in best subset	Standard regression coeff	p	Contrib to R^2	R^2	p	Other significant variables not in equation
iron	.45	.07	.03			
Diarrhea (days)	-.18	.05	.05			

The factors relating to attained weight, fat stores and rate of weight gain are similar to those for length. In addition, negative effects of maternal illness and mild and severe illness in the toddler are seen on the rate of weight gain.

Summary

The main characteristic of the toddler growth period from 18 to 30 months is that the toddler, although stunted and under weight for age but not for length, grows at a fairly constant rate. This rate is within normal limits, albeit at a low level for length (10th to 30th percentile), but at or slightly below the reference median values for weight gain. Although there is a very slight improvement seen in the mean z-scores for length by 30 months, no significant catchup growth is seen. The slight improvement may be accounted for by the termination of the severe food shortage and less illness in the older toddlers.

Total energy intake, and the quality of the diet in the toddler and in the mother and parental size are all positively related to the child's length. Illness and household size have adverse effects. Household size, particularly the total number of young children, have negative effects on the toddler's length and to a lesser extent on weight mediated by decreased quantity and quality of food intake in toddlers and their mothers. A large number of young children places a strain on a limited household food supply (see Chapter Two). Familial attributes of SES, literacy and sanitation all support growth of the toddlers.

The main restraints for catchup growth, for length in particular, and for which there are feasible interventions, are the poor quantity and quality of the diet, non iodized salt use and morbidity.

SCHOOLERS

Schoolers are thin, stunted and underweight for age and show no appreciable catch-up growth between 7 to 9 years of age. Although of small size they, like the toddlers, show incremental growth rates between the 3rd and 10th percentile for height and the 10th and 20th percentiles for weight, all within normal limits. The incremental growth percentiles for height and weight are slightly higher for girls compared to boys, although their z-scores for attained height and weight/age are lower than those of the boys.

Food Intake

Energy intake for schoolers is low, at 71 to 78% of recommended intake depending on the assumption made about activity level (11). Schoolers activity, especially for the boys, is more than moderate, with extensive walking and running long distances each day and tasks of hauling water and fuel.

In addition to low energy intake, intakes of animal protein, fat, zinc, calcium, vitamin B_{12} and iodine are considered deficient. The presence of iodine deficiency was demonstrated by the presence of goiter in 8% of children, low thyroid hormone levels in 11% of schoolers and low use of iodized salt among study households (see Chapters Two and Six).

Attained height at eight years correlates with fat intake and animal protein, and attained weight/age with total kcal, carbohydrate and fat intake (see Table 5.19).

TABLE 5.19.
Relation between food intake and schoolers size (sexes combined)

	Height/age z-score n=118	Weight/age z-score n=118
	r*	r
Kcal/day	NS	.30
Fat g/day	.35	.30
Carbohydrate	NS	.29
Animal protein g/day	.22	NS

* Pearson's correlations (2-tailed, p<.02 to .008)

When a regression is calculated of the child's dietary factors on the child's z-score for height/age then 32% of the variation in height is explained by food intake (a composite variable).

As found by Murphy, Calloway and Lien with the toddlers, height, both attained and slope of linear growth related positively to the dietary pattern that includes fat, milk, wheat, rice, animal source heme protein, sugar, potatoes and beans (see Table 5.14). For the slope of linear growth the food group containing millet and maize correlated negatively with height. The fiber and phytate content is higher in the maize predominant group, which has implications for zinc and iron bioavailability.

In regard to iodine deficiency, both height and weight relate positively to iodized salt use and to the thyroid hormone FT4, even after controlling for the effects of SES (iodized salt use is highly correlated with SES). The relationship of zinc deficiency and of B_{12} to growth have yet to be examined.

Parental Size

A regression of parental size, mother and father combined and separately, on schooler's attained height shows a significant relationship. Mother's height accounts for 40% and father's 20% of the variance in the child's attained height. The greater influence of maternal height on the child's height was also noted for the toddlers (see Table 5.20).

TABLE 5.20.
Proportion* of height variance of Embu toddlers and schoolers explained by parental height†

	Height/Age Z-scores		
Age (months)	Maternal Height	Parental Height	Parental Weight (Mo+Fa) %
	R^2	R^2	R^2
30	.31	.5	.20
96	.40	.20	.26

* R^2 x 100 = proportion of variance, all R^2 values $p<.05$-.01
† Adopted from Beaton and Calloway, Nutrition CRSP Final Report. University of California, 1987.

ADULTS

The adults retain low z-scores, particularly for height. The men have the lowest z-scores for weight and body mass index, whereas women have z-scores for weight near the median of the reference values. Although some variability in adult height is seen with 10% attaining z-scores of zero or above zero for median height, the majority of adults probably have not reached their genetic potential and are at a mean z-score of -1.5 for height.

Use of mid-parent height to predict the child's expected height should be done with caution. Parental size much more reflects a shared environment of limited food intake and illness rather than representing a fulfilled genetic height. Household socioeconomic score, literacy and parental educational level relate positively to adult stature.

FUNCTIONAL SIGNIFICANCE OF STUNTING

Stunting due to chronic PEM, in addition to poor food intake is accompanied by a host of factors reflecting poverty, such as increased morbidity, poor sanitation, lack of access to safe water, lack of medical care, low literacy, and poor educational status of the family. Therefore in any evaluation of the functional impact of stunting the above co-existing conditions associated with stunting should be controlled for.

The following functional outcomes associated with stunting or poor linear growth are summarized below in Table 5.21. Those relationships that are bivariate and those that control for intervening or modifying factors are so indicated. Full descriptions of each are found in relevant chapters.

TABLE 5.21.
Functional effects of stunting or reduced linear growth (-1.5 to <-.20 z-scores for stature)

Function	Outcome	Age group & variable (+) or (-) relationship	Type of analysis
Morbidity	ALRI*	Toddlers - length/age	Risk ratios (hazard model) controlled for season, altitude, SES changing nutritional status
	Cell-mediated immunity	Toddlers + length/age slope	Bivariate
	Severe illness (% days ill)	Schoolers height/age	Bivariate
Cognitive	Bayley Motor	Infant 6 mos + length/age	Bivariate
	Creative play and Bayley mental	Toddlers + length/age	Multiple regression controlling for physical caretaking, caretaker - child interactions, home environment
	Cognitive score	Schoolers + height/age girls only	Multiple regression controlling for parental literacy, duration of schooling
	Playground activity level	Schoolers + height/age	Multiple regression controlling for parental literacy, duration of schooling, SES
	Raven's	Adult height +	Bivariate
Reproduction	Delivery complic.	Women's - height	Odds ratios
	Newborn size	Women's + height	Bivariate
Growth	Height/ length (all children)	Maternal & + paternal height M>F	Bivariate

* ALRI: acute lower respiratory infection

CONCLUSIONS ON STUNTING

The origin of the early onset of growth failure in the Embu infant is found in the infant's intrauterine experience. Embu infants are born with a mean reduced length, relative to mean birth weight. Maternal energy and zinc intake during pregnancy are positively associated with infant's birth length. Of the newborns, 16% are considered to have intrauterine growth retardation and such infants show little, if any catch-up growth postnatally (12). An expression of IUGR may be short birth stature with only a slightly lowered birth weight. The picture is even more complicated because of the fact that deficient maternal intake of iodine, B_{12} and zinc occur simultaneously and are relevant to growth.

The mother's early nutrition and growth experience and her size upon entry into the child bearing years influences infant growth. The consequences of low pregnancy food intake with resultant poor pregnancy weight and fat gain and loss of body fat, weight and muscle mass in the last months of pregnancy set the stage for sub-optimal lactation performance.

The question arises as to whether maternal energy intake (1700-1800 kcal/d) during lactation is sufficient to support adequate normal milk production and infant growth, the mother's daily activities and to prevent maternal depletion. Although energy intake in lactation increases by 300 to 400 kcal above a very low pregnancy energy intake, this may still be insufficient to produce breast milk of adequate quantity and quality to fully support optimal growth in the infant. The mother enters lactation with a mean of 1.5 kg of body fat or potential 13,500 kcals for lactation, which does not even supply an additional 100 kcal/day throughout lactation. Moreover, time allocation studies cited in Chapter 8 show lactating mothers to double their inactive time, as in late pregnancy in order to conserve energy expenditure.

In toddlers, schoolers and adolescents no appreciable catchup growth is seen. What is striking about the toddlers and school age children is that, already stunted, they grow at rates for linear growth, weight gain and weight/stature which are within normal or at low normal levels (NCHS). The menarcheal girls are also of interest. There is a slight improvement of z-scores in height from -1.9 to -1.5, due to partial catchup growth in late adolescence. Adult z-scores for height for men and women are about -1.5. The status quo for all children's groups is maintained because food intake remains at about 75-80% of the recommended intake for age and sex and is inadequate for catch-up growth.

About 5% of women and 10% of men have z-scores above the median reference height, but one can hardly say that the adults generally have achieved their full growth potential for height. Height in adults does correlate significantly with SES, literacy and education level. Great caution is needed in trying to predict a child's ultimate stature from mid-parent height or "genetic potential" where the parents themselves have not achieved this, restrained by a diet deficient in energy and micronutrients. In addition, the adverse effect of frequent infectious illness on food intake and growth cannot be overstated. Suggestions for intervention will be presented in Chapter 10.

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CHAPTER SIX.
COGNITIVE AND BEHAVIORAL OUTCOMES

INTRODUCTION

The studies of cognitive function have focused on determining the effects of food intake and nutritional status on the cognitive abilities and behavior of infants, toddlers and children, including school performance in older children. Because parental attributes, family rearing environments and morbidity are intertwined with cognitive outcomes, these are taken into account as well. The three groups of children studied consist of groups of 110 to 130 children at each of three age periods: infants (0-6 months), toddlers (18-30 months), and schoolers (7-9 years). The infants were followed up at 30 months and 5-years of age, toddlers at 5 years, and the 7-9 year olds were followed to 12-13 years so that long term outcomes could be determined. Observations of caretaker-child interactions, school behaviors and activities and cognitive and literacy testing of parents provide essential information for interpreting the results and separating the effects of nutrition from other influences on cognitive function and behavior.

In phase I of CRSP, the importance was established, not only of the relationship between food intake and cognitive function, but also of the influence of home conditions and parental attributes on the cognitive performance of toddlers. In the second phase of the project, in-depth analyses were conducted to examine the role of diet quantity and quality, morbidity and long term predictors of cognitive function based on follow-up studies of the children. School performance and classroom and playground behavior have been studied in relation to both diet quantity and diet quality. Examination of infant cognitive performance in relation to maternal nutrition during pregnancy and lactation and to infant nutritional status have only recently been initiated and much work has yet to be done. However, progress has been made on infant-caretaker interactions and child rearing and cognitive outcomes.

For a more complete discussion of methodology and findings, please see the 1987 Kenya CRSP Final Report and the papers referenced in each section.

INFANT COGNITIVE FUNCTION AND BEHAVIOR

As a first step in understanding determinants of infant cognitive function, the rearing environments and development of Embu infants were examined in order to characterize the nature and influence of these factors from the earliest months of development. The extent to which the above factors and maternal nutritional status during pregnancy and lactation are associated with these abilities in infancy is one of the main questions guiding this set of analyses. This question stems from the finding that among the Embu toddlers, nutritional status, as measured by length and weight at the toddlers' entry into the study at 18 months, was related to subsequent play and verbal and cognitive development (1). It would also be expected that the level of motor development during infancy would be related to the infants nutritional status.

The nature of the relations between the early social rearing environment of the Embu infants and their later cognitive skills are more difficult to predict. Studies in Western countries find associations between the social environment in the first year of the infant's life and later developments. These become more robust when rearing conditions are also measured in the second year of the infants' lives or later (2). Based on these findings, it would be expected that Embu infants who are cared for, talked to, and responded to more might develop better motor and interaction skills later in infancy.

Methods

These analyses include full term normal infants (>37 wk gestational age), followed throughout pregnancy to six months of age.

Home observations were conducted to assess the kind of interactions in which the infants were involved, and the types of infant behaviors that could not be measured in structured testing situations. The frequency of vocalizing, crying, smiling and laughing were considered. Observations were made during daylight hours alternating between mornings and afternoons. These were made six days a week and carried out only if the infant was well at the time of the visit. A time sampling method was used in which behavioral observations that occurred in a 30 second interval alternated with a 30 second interval used for recording of data. Observations were done for periods of 120 minutes. If 120 minutes of data were not collected, the observer returned to the home to complete the time period. Because of variations in the length of individual observations, percentage scores have been used throughout.

The social interaction and caretaker behavior patterns coded were: holds or carries, touches, and talks to the child; mutual gaze and physical care. The infant behaviors coded included: vocalizes, cries or whines, and smiles or laughs. None of the behaviors were mutually exclusive so that any number could be coded in one time frame. In addition to recording occurrence of a social interaction, the observer noted exactly who the other participant(s) were, e.g. mother, father, older sister, etc. When the infant cried or vocalized, the response was recorded as to whether a vocal, physical or combined vocal-physical response had been made. If the infant was taken to a location where he or she could not be seen for at least 10 minutes, then the time period was coded as out of view and the observer stopped recording.

The reliability of the observational procedure was determined as follows: 11 infants were observed by 15 enumerators, working in pairs, each pair observing 2 infants for a 40 minute period. Observers made their observations independently. Interrater agreements for the interaction variables, responsiveness measures and infant behaviors were uniformly high with Pearson's correlation coefficients ranging from $r = 0.63$ to 0.99.

Bayley Motor and Mental Scales

Selected items (13 to 46) on the Bayley Motor scale were administered to all infants at 6 months of age. These items cover an ability range from 2 to 12 months. In the gross motor area, abilities range from sitting with support to walking alone, while the fine motor abilities tested include finger use in picking up a small piece of food and type of grasp used to hold a block. Four local women who were experienced in child care were extensively trained by a senior investigator to administer the test and were supervised closely on a day to day basis by a Kenyan psychologist.

Following administration of the Bayley Motor Scale, the tester filled out the items on the Bayley Behavior Record, which describes the infant's reactions to the examiner and certain objects. Extensive pilot testing was conducted in order to obtain agreement on the meanings of the items and on the ratings. Only those 10 items with interrater correlations greater than 0.56 were included in the analyses.

Follow-up Measures at 30 Months

When the infants reached 30 months (± 2 weeks) of age the Bayley Motor and Bayley Motor Scales were re-administered. On the Bayley Motor Scale, all items from no. 57 to the end of the test were given with the exclusion of the 9 items requiring a walking board or stairs. The total number of items passed rather than a developmental quotient was recorded. All items on the Bayley Mental Scale from no. 116 on (and no. 113) were assessed with some exclusions and substitutions. Modifications were made in the Bayley Mental Scale so as to make the test items more culturally appropriate in the Embu context. Test performance at each age was summarized by a raw score. Because standardization of the Bayley has never been done in Kenyan infants, raw scores rather than develop mental quotients were used.

Socioeconomic Status and Literacy

Families were characterized by the socioeconomic status (SES), literacy and cognitive abilities of the parents. Socioeconomic status was measured with a scale that rated the amount of land and material objects possessed by the family, the quality of the homestead, and outside income. Parental literacy was tested by their ability to read and comprehend passages of text from local school textbooks. The test score was equal to the total number of passages read aloud on which two of three questions were answered correctly. Simultaneous testing of 29 adults by two examiners showed perfect agreement on scoring. The Raven's Progressive Matrices were used to assess performance type intellectual abilities in both parents. This test is thought to be a relatively good measure of general intellectual ability and is not a language-based test.

Nutritional Status

Nutritional status of the mother and her infant were assessed by measuring food intake on two consecutive days per month and making anthropometric measurements (weight, height, MUAC, fat folds, and head circumference in the infants) monthly during pregnancy and lactation. The infants were all breast-fed throughout the first six months and most were also provided with supplementary feedings.

Results

Rearing Conditions

In order to assess the impact of maternal and infant nutritional factors on cognitive performance and behavior, an understanding of the effects of caretaker interaction and physical care on the development pattern are essential. Patterns of care and changes over time were described using the following rearing variables: physical care, holding, touching, talking to, and mutual gaze.

The rearing variables were analyzed using ANOVA's in order to determine whether males and females were treated differently, whether there were significant differences in the percentage of caregiving among individuals, and whether caregiving changed as the infant matured. The amount of time devoted to physical care and to carrying and holding the infants declined as would be expected, from 2 to 6 months of age. Physical care declined from 26% of the first visit to 15% by 6 months and carrying and holding declined from 53% of the first visit to 35% by 6 months. In contrast, the infants had increasingly more physical contact other than direct care and carrying and were talked to more as they matured.

The only significant effect of gender was that the male infants were involved in slightly more mutual gaze with other individuals than were the female infants. This is similar to the finding that male toddlers were more involved in social interaction than female toddlers. Mothers and older sisters were the predominant caregivers, carrying the infants, providing physical care, and talking to them more than any other individual in the compound. The infants were talked to for 20% of the intervals observed with most of this conversation emanating from the mother and older sister. The infants were carried or held for about 44% of the intervals and were provided physical care for about 20% of the intervals.

Infant Behavior and Caregiver Responsiveness

Infant vocalization increased from 10% of the intervals to 13% by the age of 6 months, while crying accounted for about 11% of the intervals. Responsiveness to the vocalizations and cries of the infants were analyzed by gender and type of response using ANOVA. There were significant effects of type of response but not of gender. Caregivers responded to the cries of their infants mostly with vocal responses, and less often with combined physical and vocal responses. Almost all responses to infant vocalizations were verbal rather than physical.

Consistency in Rearing Conditions and Behavior

Since individual children were exposed to different rearing conditions, the question arises as to whether there was consistency in their experiences from one time period to another. Correlations computed between the variables from one visit to the next showed that the greatest consistency was found in the extent of holding and carrying. Infants who were held or carried a great deal in the first visit were likely to be held or carried in subsequent visits. Duration of infant smiling and infant crying over all three visits were also consistent. However, individual differences in rates of vocalization did not become stable until the third visit.

Rearing Conditions and Infant Behaviors

A principle components analysis of the seven rearing variables was carried out since these variables were intercorrelated. A three factor solution accounted for 68% of the variance in infant behaviors. The first factor, reflecting the extent of responsiveness to infant distress and vocalization as well as frequency of talking to and carrying the infant, accounted for 28% of the variance. The second factor, reflecting how much the infant was touched and talked to, accounted for 23% of the variance. The third factor reflected the extent of mutual gaze and physical care of the infant and accounted for 18% of the variance.

Relationships were sought between rearing conditions, and the extent to which the infants vocalized, smiled, and cried in the last observation session. The only infant behavior associated with rearing conditions was smiling; infants who smiled more during the last home observation when they were 5-6 months of age had higher scores on home rearing factor scores, $r = .25$ to $.28$, $p < .05$. Thus, infants involved in more overall interaction showed more positive affect during home observations.

Relations between Rearing Conditions and Test Performance and Behavior at 6 months

Correlations were computed between the home rearing factor scores and the 6-month Bayley Motor Scale scores and Bayley Behavior Record factor scores. There were significant associations between the home rearing factor scores and the 6-month assessment measures. Infants who were responded to more by the caretaker, usually the mother, through the first six months, had higher Bayley Motor Scores and higher ratings on the factor reflecting alertness and attention. Infants who were touched and talked to were found to be more socially oriented, while those who were cared for and involved in mutual gaze were rated as more exploratory during the testing session.

Relations between Nutritional Factors, Home Rearing Conditions, and Infant Behaviors

The infant's mean length and weight from 0 to 6 months of age, and supplementary food calories were examined in relation to the infant's behaviors and abilities. The longer infants smiled and vocalized more at 6 months than shorter infants. A relationship was observed between Bayley Mental Score and infant length and supplementary calories. However, both these variables were correlated with SES. Both SES and z-scores for height for age entered into a hierarchical regression model for cognitive outcomes, but infant supplemental calories did not.

Relations between Rearing Conditions, Infant Characteristics, and Test Performance at 30 Months and 5 Years

Correlations were computed between the rearing factor scores obtained for the infant from 0 to 6 months and their test performance at 30 months and 5 years. The only statistically significant association ($p<.05$) found was that infants who were more engaged in face to face interaction in the first 6 months of life had higher Bayley Motor Scores at 30 months and infants who were rated as more exploratory at 6 months had higher Bayley Motor scores at 30 months. In addition, scores on the verbal meaning test administered when these infants became 5 years old were correlated with the extent to which they smiled and vocalized, their motor abilities and their behavioral ratings of sociability and exploration at age 5 to 6 months. Correlation coefficients ranged from $r = .21$ to .31 ($p<.05$). Bayley Mental and Motor Scores at 30 months were also predictive of later verbal competence, with coefficients ranging from $r=.31$ to .42, $p<.05$. Thus, early rearing and maternal-infant interactions had direct effects on future development.

Conclusions

These findings suggest that nutritional status, rearing and interaction with caregivers and environment, influence behaviors and abilities in infancy. Further analyses using multivariate models will be useful in interpreting these relationships. Further work will examine maternal pregnancy and lactation factors in relation to energy and micronutrient intake. Iodine, zinc, vitamin B_{12} and iron are of particular interest in relation to the growth and cognitive development of infants since these nutrients are low in the Embu diet. Vitamin B_{12} is low in breast milk and is of particular concern.

COGNITIVE FUNCTION AND BEHAVIOR IN TODDLERS

The relationship between mild to moderate malnutrition, as measured by food intake and anthropometric status and developmental outcome was explored in 110 toddlers, 18-30 months of age. Developmental outcome was evaluated at 30 months of age by the Bayley Mental and Motor scales and by evaluation of play behaviors. Verbalization and play during months 15-30 were evaluated, including interactive patterns with care givers, and play with objects and verbalization. Simple, functional and symbolic play were assessed by the use of home observations. Family background variables, including SES, parental IQ and literacy, and home rearing conditions, including physical care, carrying and social interaction with the caregiver were assessed. Weekly morbidity data were collected from the 18th to 30th months as discussed in Chapter 3.

Relation Between Home Rearing Conditions and Cognitive Development

The relation between home rearing conditions and cognitive development were explored in-depth (2). Observations of the rearing environment showed that Embu toddlers are cared for primarily by their mothers and older sisters, and their social interactions are generally with siblings and other children. While adults do not play with toddlers very much, both mothers and older sisters talk to the toddlers a great deal and are responsive to the toddlers' verbalizations. At 15-18 months, toddlers are still carried on their mothers' and sisters' backs, but this declines over the next few months except for those toddlers who are small and less healthy. Overall amount of play remains constant but simple, relational play declines while symbolic play increases as the toddlers mature.

Rearing conditions were found to be concurrently and predictively associated with toddler play and social behaviors as well as with skills measured by a revised version of the Bayley scales. Toddlers who were talked to more, involved in more social interaction, and carried less were more adept on the Bayley items, vocalized more in their home surroundings, and showed more high-level or symbolic play. In addition, toddler abilities at 30 months of age were related to levels of paternal literacy.

Relationships Between Nutrition and Development in Toddlers

The relation between food intake, anthropometric status and development was examined (3). Statistically significant correlations between nutritional measures and developmental outcomes were found. These included correlations between: food intake and anthropometric status, nutritional variables and developmental outcomes, nutritional variables and family background-home rearing conditions, and family background-home rearing conditions and developmental outcome. To determine which variables best predicted Bayley Mental scores at 30 months a multiple regression analyses was used which included anthropometric measures, family indices, home rearing variables, and child characteristics observed in the home (see Table 6.1). Four variables contributed significantly to the stepwise regression, accounting for 25% of the variance in Bayley scores. In order of entry, these variables were weight at 30 months, of age, the extent to which the child verbalized in the previous 15 months, the frequency of social interactions with the mother and the frequency of touching experienced by the child.

TABLE 6.1.
Prediction of Bayley Mental score at 30 months of age

Variables entered	R^2 change from previous step	F	p
Weight	0.078	9.56	0.003
Amount of verbalization	0.053	6.50	0.013
Social interaction	0.067	8.27	0.005
Touched	0.048	5.92	0.17
Total R^2	0.25		

Sigman M, Neumann C, Carter E, Cattle DJ, D'Souza S, Bwibo N; 1988.

Food intake was related to anthropometric status, play behaviors, and total amount of verbalization among children even when the potentially confounding effects of certain family background and home rearing variables were held constant. No direct association between food intake and cognitive skills, as measured by the Bayley Scales was observed. However, there is indication of an indirect path of association through the child's physical size and possibly through other characteristics such as symbolic play, $r = .20 - .25$, $p<.05$ ($n=110$) behavior and loquaciousness. Children who were better fed particularly with fat and animal protein, also played and verbalized more, using symbolic play. Both family background and home rearing variables were related to outcome. However, home rearing variables were consistently stronger predictors and were related to outcome even when nutritional variables were considered, whereas family background was not. These findings suggest that changes in care-giving practices do make a difference for the child. The extent to which the toddler was held or carried was negatively associated with development in all domains. Such a toddler has more illness and is withdrawn from interaction with and exploration of the environment, which are important to cognitive development.

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

Role of Morbidity on Cognitive Development in Toddlers

The effect of illness on cognitive development in toddlers was examined, as illness often leads to a reduction in food intake, poorer nutritional status, and a concurrent reduction in activity level and exploration of the environment. Previous analyses showed that toddlers who were carried the most by their mothers were found to have more illness, less opportunity to interact and explore the environment, and did less well cognitively. This analysis explores the extent to which morbidity in 110 mild-to-moderately malnourished Kenyan toddlers was associated with developmental outcomes (4).

Female toddlers who suffered more illness generally did not perform as well on developmental measures as their healthier female peers. These children vocalized and played less and the frequency of both simple (immature) and symbolic (mature) types of play were decreased at 30 months. Girls with more illness also did not perform as well on the Bayley mental scales at 30 months and on the cognitive battery at five years. For the males, development was largely independent of morbidity. Rather morbidity was related to patterns of caregiving for both boys and girls, but it was not directly associated with SES or food intake. However, girls who were ill more often, were shorter and lighter.

Multiple regression analyses were performed to determine whether morbidity continued to relate to developmental outcomes after care giving, family socioeconomic status, food intake, and anthropometric variables were considered. The developmental outcomes selected were those significantly correlated with morbidity for the girls ($p<.05$): vocalization and play during the 15th to 30th month, Bayley Mental score at 30 months, and the follow-up cognitive measure at 5 years (see Table 6.2). These variables were force-entered into the regression equation first. In instances where two related variables such as animal protein and fat were strongly related to a developmental outcome, only the stronger correlation (fat) was force-entered to reduce problems of collinearity.

TABLE 6.2
Consideration of other variables in the relation between illness and developmental outcomes in toddler girls

Outcome Variable	Related variables correlated p<.05 with outcomes	Significance of morbidity in regression after force-entering related variables
Vocalizations	Hold Touch Talk kcal Fat Length (R^2 = .27)	R^2 = .44 F-to-enter = 10.1 p = .003
Play	Hold kcal Fat Length (R^2 = .27)	R^2 = .47 F-to-enter = 6.2 p = .02
Bayley Mental	Social Talk IQ Length (R^2 = .23)	R^2 = .26 F-to-enter = 1.1 p = .31
Follow-up cognitive measure	SES* Literacy (R^2 = .42)	R^2 = .55 F-to-enter = 9.7

*Socioeconomic status
Neumann C, McDonald MA, Sigman M, Bwibo N. 1991.

The results showed that for vocalization and play, morbidity explained a statistically significant portion of the variance in outcomes after other relevant variables such as care giving, SES, food intake, and body size were considered. Female toddlers who experienced more morbidity developed less well. Illness in and of itself was associated with decreased play and vocalization during the 15th to 30th month period.

Further analyses of the differences between male and female toddlers suggest that the gender effects in this study may be due to a group of girls who were seriously ill more often than the boys. Subsequent studies should examine whether illness negatively impacts development only when some critical level is exceeded.

Prediction of Cognitive Competence in Schoolers from Toddler Nutrition, Family Characteristics and Abilities: A Follow-up Study

The toddlers described above were followed up about three years later, when they turned five years of age, with cognitive testing and anthropometric measurement. The association between cognitive competence in the now 5 year old children, and earlier nutritional factors, family conditions and toddler characteristics were explored (4).

Cognitive competence at 5 years, 3 months was assessed by a verbal meaning test[1] and Ravens colored progressive matrices. A composite cognitive score was calculated for each child, combining the two scores. Parents were also asked about the number of months their child had attended school. For the purpose of analysis, school attendance was transformed into a dichotomous variable reflecting whether or not the child had ever attended school.

The findings show that males and females did not significantly differ in mean cognitive scores, nor were any gender differences between early measures and the cognitive scores significant. Thus, data were combined for males and females. Food intake during the 18th to 30th months, and height at 30 months were associated with cognitive skills at 5 years. Animal protein, a measure of diet quality, related more strongly to cognitive outcomes than did energy intake (kcals). Measures of family background, abilities of the child as a toddler, morbidity as a toddler and current schooling were also associated with cognitive abilities at 5 years.

In order to test whether nutritional factors contributed independently to cognitive skills beyond the associated environmental effects, a regression was calculated in which all family background, caregiving and schooling variables were entered first. These variables accounted for a total of 29% of the variance in the 5 year cognitive score. Animal protein added significantly to the regression equation, increasing the R-square value to 0.36 ($F=6.68$, $p<0.05$).

To test the effects of family background, caregiver and schooling variables above and beyond those of food intake and anthropometric status an additional analysis was carried out. After forcing the nutritional and anthropometric variables into the regression equation, parental literacy was found to contribute significantly to the equation increasing the R-square value to 0.31 ($F=4.68$, $p<.05$) from 0.27. Thus, the nutritional and environmental resources of the family were independently influential.

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[1] Standardized on Kenyan children.

Finally, stepwise multiple regression was calculated to determine which set of variables best predicted cognitive competence at 5 years (see Table 6.3). Early nutritional variables, family background, care giver characteristics, schooling and toddler measures were considered. The three variables that predicted 30% of the variance in cognitive competence at 5 years, were animal protein, SES and 30 month Bayley mental score. Thus, cognitive competence at 5 years was best predicted by a combination of earlier nutritional, family and toddler characteristics.

Table 6.3
Multiple regression on 5 year cognitive score

Variables entered	R^2 change from previous step	F	p
Animal protein	0.166	18.8	0.0001
SES	0.075	8.5	0.005
Bayley mental score 30 mos	0.062	7.1	0.01
Total R^2	0.303		

Sigman M, McDonald MA, Neumann C, Bwibo N. 1991.

The results of this follow-up generally support previous findings that both nutritional and environmental conditions relate to the cognitive skills of the school-age child. Both food intake and anthropometric status related to cognitive score at 5 years. The total level of calories available to the toddler between 18 and 24 months was predictive of later cognitive skill. The amount of fat and animal protein consumed by the toddler was important, and the contribution of fat and animal protein was independent of the contribution made by the educational and financial resources of the family. This is not surprising, as fat is a concentrated source of energy and animal protein contributes micro-nutrients, especially iron and zinc in a bioavailable form to the diet.

Environmental variables, especially relatively stable family characteristics such as SES, parental literacy and IQ were also related to cognitive skills. Furthermore, both nutritional and environmental factors added to prediction of cognitive outcome even when the effects of the other had been considered.

COGNITIVE FUNCTION AND BEHAVIOR IN SCHOOLERS

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

The relations between cognitive function and classroom behavior of children ages seven to nine and their nutritional status, family characteristics, and duration of school attendance were examined (5). Cognitive measures consisted of an assessment of verbal comprehension and of performance abilities. Observations of classroom behaviors were carried out using a time-sampling procedure to assess the extent to which the children paid attention to classroom activities. Nutritional measures included the child's average consumption of calories, protein, carbohydrates, fat, and animal protein for their total participation in the project. Anthropometric measurements include mean z-scores for height-for-age, weight-for-age, and weight-for-height attained over the period of observation. Family characteristics included were the overall socioeconomic status, parents education level and literacy. Duration of schooling was based on the current grade of the children grouped into two levels, nursery school and first standard, and second and third standard.

Children who were heavier and taller had higher composite scores on tests of verbal comprehension and the Raven's matrices. Using Pearson product-moment correlations all of the anthropometric and food intake measures were positively associated with cognitive scores except for height and carbohydrate intakes for the boys ($p<.05$). Better nourished females were more attentive to their classroom work than their malnourished peers. Family characteristics and duration of school participation were positively associated with cognitive abilities for both boys and girls.

To determine whether duration of schooling contributed to cognitive scores regardless of age, physical stature, level of food intake, and family characteristics, a stepwise regression was calculated with the cognitive score as a dependent variable. Duration of schooling, mean intake of animal protein, weight for age, and SES entered into the regression equation, accounting for 54% of the variance. As seen in Table 6.4, the extent of school participation had the greatest effect on cognitive abilities, independent of the child's family background and nutritional status. Diet quality as characterized by the amount of animal protein, a source of bioavailable micronutrients, also appears to be an important determinant of cognitive performance. Overall, this analysis indicates that a variety of factors including school experience, and nutritional adequacy and family economic resources all influenced the cognitive skills of the children in this age group.

Table 6.4
Multiple regression on schooler's cognitive scores

Variable	R^2 change from previous step	F	p
Duration of schooling	.33	89.93	.001
Animal protein	.13	36.33	.001
Weight for age	.05	13.87	.001
SES	.03	9.49	.003
Total R	.54	...	...

The Relationship of Nutrition, Schooling and Family Characteristics to Playground Behaviors

Activity level and social peer interaction are important prerequisites for learning. The relationship of food intake and nutritional status to socio-emotional behavior and activity level in schoolers was examined (6). The setting of the school playground allowed for observation of unstructured, spontaneous behavior. This analysis also considered the relative contribution of diet quantity and quality. Earlier analyses have shown that high activity level relates positively to a composite cognitive score (verbal plus Raven's tests), $r = .29$, $p<.01 (n=109)$.

Assessments included measures of food intake and anthropometry and the outcome measures for activity level and playground behaviors. Other variables included SES and parental literacy, duration of schooling, and school attendance. A coding system adapted by Barret et. al. (7) was used to record behaviors related to three major areas: activity level, emotional state, and social interaction with peers. Each child was observed individually for a minimum of 40 minutes every other month over a period of six to eight months.

Girls and boys were similar in the infrequency of various activity levels and emotions exhibited on the playground, such as social interaction, leadership or positive peer involvement as determined by a series of t-tests. Correlations between nutrition, family and schooling behaviors and playground observations differed by gender only for aggressive behavior, as males displayed more aggression than females.

Correlations between the eight measures of playground behavior with energy intake (kcals) and a factor score for animal protein/fat showed that children who consumed more food during the study were more active than peers who ate less. Food intake variables were more robust predictors of activity level than anthropometric indicators. Children who consumed more food were also heavier and showed more leadership behavior.

As for activity level, playground behaviors were associated with overall energy intake rather than with the animal protein/fat factor. To more clearly examine the effects of food intake variables on activity levels, hierarchical regressions were calculated entering either kcals first or the animal protein/fat factor scores first. The animal protein/fat factor scores did not enter into the regression equation once kcals had been force-entered for either low or high activity. However, kcals were still correlated with activity levels after the animal protein/fat factor had been co-varied, for both low and high activity, suggesting that most of the association was due to energy intake. Further analyses showed that there was no strong evidence to suggest that prior nutritional history, i.e. height, was responsible for the associations between concurrent food intake and playground behavior.

Family and schooling variables were correlated with behaviors on the playground. Children from higher SES homes were more active and happier than children from poorer homes. The same positive pattern of behaviors was associated with increased food intake. Boys from poorer homes with parents who were less educated were more aggressive with peers. Children who had been in school longer were more active on the playground and spent less time alone.

Hierarchical regressions were calculated to determine whether food intake predicted playground behaviors after family and schooling variables and duration of schooling were entered. Energy intake continued to relate to activity levels and leadership behaviors even after SES, parental literacy, and duration of schooling were held constant. Affect was unrelated to energy intake after the contribution of associated family and school characteristics were controlled.

To determine whether family characteristics or duration of schooling were independently associated with playground behavior, regressions were calculated by force-entering kcals and then entering the family and schooling variables (see Table 6.5). When kcal level was entered first, duration of schooling continued to add significantly for low and high activity levels.

TABLE 6.5
Relations between kcal intake and playground behaviors after consideration of family and schooling variables

Outcome variable	Significance of kcal in regression after force-entering SES, parental literacy, and duration of schooling	
Low activity	$R^2 = .14$ R^2 change = .04	F-to-enter = 4.68*
High activity	$R^2 = .21$ R^2 change = .10	F-to-enter = 13.57†
Positive affect	$R^2 = .10$ R^2 change = .03	F-to-enter = 3.57
Anxious affect	$R^2 = .08$ R^2 change = .03	F-to-enter = 3.50
Leadership	$R^2 = .10$ R^2 change = .08	F-to-enter = 9.46†

* $p < .05$
† $p < .01$
Espinosa MP, Sigman MD, Neumann CG, Bwibo NO, McDonald MA. (in press).

The associations found between playground behavior and nutritional factors differ from the associations between cognitive skills and nutritional factors. The playground behaviors appear to be related more to the adequacy of energy intakes than to specific nutrients, while, according to previous analyses, the level of fat and animal source protein appear to be very important for the cognitive development of toddlers followed up to 5 years of age. Cognitive abilities also seem to depend more on prior nutrition than does playground behavior. Therefore, activity may depend more on concurrent food intake, while the development of cognitive skills is influenced by both previous and current nutritional intake. It must be noted that many Kenyan children eat little or no food in the morning and then walk long distances to school. They bring little or no food with them.

These data, along with the findings concerning the children's cognitive abilities (5) indicate the need for adequate levels and quality of nutritional intake as well as the importance of school attendance and high activity level and socialization. The finding that children must have adequate nutritional intakes in order to participate actively in social interactions and to attend to cognitive tasks is generalizable to children of all cultures, including disadvantaged children in the USA who come to school inadequately fed.

Effect of Morbidity on Cognitive Development in School Aged Children

Morbidity is another of the multiple factors associated with malnutrition and might contribute to the poor developmental outcomes seen in malnourished children. Ill children are less active and playful which can interfere with exploratory behavior, social interactions and learning. Also illness interferes with growth. Thus, the relation between morbidity and development was explored in 133 mild-to-moderately malnourished school-age children in the Nutrition CRSP study.

Correlations were computed between frequency of mild illness and cognitive and behavioral characteristics of children as severe illness was very infrequent among all schoolers. The patterns of correlations were different for boys and girls. Girls who had a higher frequency of mild illnesses in the year-long period, performed less well than their healthier female peers on the cognitive measure. They were also less active on the playground, happy less often, and spent more time alone. Thus increased illness had consistent negative associations with cognition and playground behaviors for the girls. The pattern of correlations for the boys was different in that frequency of mild illness was not significantly associated with any of the cognitive or playground behavior measures.

To determine to what extent characteristics of the child's nutritional status and environment related to physical illness correlations between these variables and mild illness were calculated (see Table 6.6). Girls from less advantaged homes and girls with fewer years in school experienced a higher frequency of mild illness. Food intake, physical size, parental literacy and attendance were not related to mild illness. For boys, the pattern was quite different. More illness was reported for boys with better nutrition, more educated parents, and more household resources. This apparent increase may be due to better reporting of illness in boys by more educated parents who may have favored sons or the better fed children may have been more active and mingled more with others.

TABLE 6.6
Relations between mild illness and nutritional, environmental and schooling variables

Nutritional:	Kcal intake	Fat intake	Height/age	Weight/age
Females	.21	.00	.11	.14
Males	.19	.21	.23*	.25*
Env't and School:	**SES**	**Parental Literacy**	**Duration**	**Attendance**
Females	-34*	-.15	-.37*	-.07
Males	.39*	.26*	09	.22

Neumann CG, NcDonald MA, Sigman M, Bwibo NO. (in press).
* Pearson's correlations (two tailed, $p<.05$)
n's are 60(70) for all correlations except literacy 58(71), duration of schooling 57(70), and attendance 42(48) for females and (males).

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To see if morbidity was associated with cognitive abilities and playground behaviors beyond the influence of the intervening variables, a series of partial correlations were calculated between SES, food intake, anthropometric status and schooling. Outcome variables studied included a composite cognitive score, low activity level, happy affect and no peer involvement. Variables which correlated ($p<.05$) with the outcome were considered as covariates. The partial correlations of frequency of mild illness with the outcome variables, after controlling for the covariates are shown in Table 6.7.

After consideration of related variables, there was no longer any association between frequency of mild illness and cognitive score. However, the partial correlations between frequency of mild illness and playground behaviors remained statistically significant (see Table 6.7). Girls who were sick more often were less active and happy and spent less time playing with peers even when food intake, SES and schooling variables were taken into account. Thus physical illness in these school-age girls related negatively to playground behaviors, above and beyond other factors associated with malnutrition.

TABLE 6.7.
Consideration of other variable in the relation between mild illness and cognitive and playground behaviors in females

Outcome variable	Related variables correlated $p<.05$ with outcomes	Significance of morbidity in regression after force-entering related variables
Verbal meaning and Ravens	kcal intake fat intake weight/age SES duration of schooling parental literacy (R^2=.57)	R^2=.58 F to enter =0.7 p=.3
Low activity	kcal intake fat intake SES duration of schooling (R^2=.24)	R^2=.33 F to enter =4.9 p=.03
Happy affect	kcal intake fat intake SES (R^2=.24)	R^2=.31 F to enter =4.2 p=.05
No peer involvement	fat intake duration of schooling (R^2=.06)	R^2=.14 F to enter =3.7 p=.06

Neumann CG, McDonald MA, Sigman M, Bwibo No. (in press).

By separating the girls into "sick" and "well" groups, female school-age children who suffered more mild illness performed less well on developmental measures than their healthier female peers. These children scored less well on a cognitive assessment and on a school achievement test. On the playground such girls were less active, happy and social than their healthier peers. Furthermore, relations between morbidity and playground behaviors (but not cognitive tests) in the females remained statistically significant when other variables, such as SES, parental literacy, food intake, and anthropometry were considered. For the males, cognition and play behaviors were independent of morbidity. Why morbidity might impact girls but not boys in this culture, can only be surmised. One hypothesis is that the boys may in subtle ways receive more parental attention, particularly from their fathers, thus overcoming the effects of illness.

Studies in diverse cultures have consistently reported that mental development in females is more affected by malnutrition than in males (9). The present study suggests that physical illness must be considered as yet another of the multiple insults accompanying malnutrition which may affect development differentially for males and females.

Functional Effects of Marginal Iodine Deficiency in Schoolers

There is growing recognition that iodine deficiency (IDD) produces a variety of effects depending on the severity of the deficiency. The spectrum of effects ranges from the extreme situation of cretinism, with severe neurologic impairment and retardation to subtle impairments of growth and cognitive function (10). While there is extensive documentation on severe IDD, there is relatively little documentation on the possible effects of marginal IDD on learning and growth.

In the study area of Embu district mild IDD is present (see Chapter 2). In addition to ongoing measurements of food intake, growth, cognitive function, school performance, and behaviors; thyroid hormone levels were measured on a sub-sample of children and adults. Thus, the Kenya CRSP provided an excellent opportunity to address the question of possible functional consequences of mild iodine deficiency. Because IDD is readily prevented and amenable to treatment it was felt important to investigate the possible cognitive and growth consequences of mild iodine deficiency in children.

Methods

All data collection methods except measurement of thyroid hormone have been described previously. The sample for this analysis consisted of 133 Embu school children, 73 boys and 60 girls, with a mean age of 7 yrs and 7 months (SD = 4.2 mo.). Physical examination showed these children to be free of auditory, visual, mental or motor handicaps, no cretinism was observed in the area.

Thyroid, Thyroid Hormone and Thyrotropin (TSH) Levels

Thyroid size was measured during monthly physical examinations by the two physicians using bimanual palpation according to the scale devised by WHO (11). Thyroid hormone and thyrotropin levels were measured by immuno radiometric assays.[2] Specific measures included total Thyroxine (T4), free Thyroxine (FT4), Triiodo Thyronine (T3) and Thyroid Stimulating Hormone (TSH). Because of small specimen sizes reverse T3 and TBG could not be assayed. Appropriate quality control methods were carried out and laboratory "norms" established.

Results

Iodized salt was used by 27% of study households. Salt is used in cooking but not added to individual portions. The mean daily household intake of iodized salt was 5.1 ± 6.1 g (x± SD). The use of iodized salt correlated positively and strongly with household SES, level of educational achievement by the father and "modernity status" (a composite variable comprised of household use of banks, post office, telephone, reading newspapers, etc.), r=.26 to .43, p<.002-.0001 (n=133).

Clinical Goiter

Schoolers showed enlarged thyroid glands (clinical goiter) by visual inspection and palpation in 8% of the girls and in 3% of the boys. Only 2% were of grade 2 size. Furthermore 15% of non-pregnant women and 24% of pregnant women had palpable goiters of which 4% were grade 2 goiters.

Thyroid Hormones

Low T3 and T4 levels were seen in 8% to 11% respectively and elevated TSH in 8% of the children. Borderline low values of T3, T4 and FT4 were seen in 4 to 9%, and about 10% of the children had borderline high values of TSH (see Table 6.8).

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[2] The assays were performed in the Endocrine Assay Laboratory Mental Health Clinical Research Center, University of Chapel Hill, NC. Dr. Arthur J. Prange, Director.

TABLE 6.8
Thyroid hormone levels in Kenyan school children

Hormones	Norms*	Mean ± SD	Range	% Low	% Borderline
T3 (ng/dl)	75-200	137 ± 53	(51 - 274)	8.3	4.2
T4 (μg/dl)	5-12	7.6 ± 2.4	(3.5 - 12.0)	11.4	8.8
Free T4 (μg/dl)	0.7-2.0	1.2 ± 0.3	(0.8 - 3.0)	1.0	9.0
TSH (μU/ml)	≥3.9	2.4 ± 1.1	(0.8 - 4.8)	8.4 (elevated)	10.3

* Normal adult values established by Endocrine Assay Laboratory, University of North Carolina. Norms are lower than for the radio-immunoassay method for TSH.

Expected relationships were observed between household iodized salt use and thyroid hormone levels in the children. The use of iodized salt was positively correlated with the children's T3 levels, $r=.54$, $p<.003$ ($n=29$). Thyroid enlargement showed a significantly negative relation to iodized salt use, but no relation to thyroid hormone or TSH levels. Thyroid size did not correlate with thyroid hormone levels.

Iodized Salt Intake and Cognitive Function, School Performance and Behaviors

Because SES was found in earlier analyses to relate strongly to cognitive outcomes and to household iodized salt use, SES is controlled for in these analyses and partial correlations presented. Household iodized salt use was positively associated with mean school examination scores and with scores on the Raven's Matrices, Verbal Meaning, Picture Drawing and Block Design tests (see Table 6.9).

TABLE 6.9.
Relation between iodized salt use and cognitive test scores, school performance, and behaviors: controlling for socioeconomic status

Use of iodized salt versus:	n	r*	p
Raven's Matrices Scores	133	0.24	<0.02
Verbal Meaning Test	133	0.24	<0.005
Picture Drawing	131	0.25	<0.004
Block Design	131	0.17	<0.056
School Examination Scores	133	0.20	<0.05
Percent "Off-Task" in Classroom	133	-0.21	<0.02
High Activity Level in Schoolyard	133	0.23	<0.01

* Pearson's product from correlations - 2-tailed - parental correlations

Iodized salt use also showed statistically significant associations with school behaviors and activity level after controlling for SES. The more iodized salt used, the less was the child's "off-task" behavior in the classroom and in the playground setting, the higher the child's activity level (see Table 6.9).

Thyroid Hormone Levels and Cognitive Function, School Performance and Behaviors

Triiodo thyronine (T3) levels showed a strong positive and statistically significant relation to school examination scores after taking SES into consideration. Moreover, when children were sorted into the uppermost and lowest quartile groups by values for T3, a much higher mean school examination score was found for the upper T3 quartile compared to the lowest T3 quartile group, 158$\pm$38 vs. 95$\pm$38 points respectively, $T=2.9$, $p<.01$. As for other specific cognitive tasks, verbal ability was related positively to FT4 levels (see Table 6.10).

TABLE 6.10.
Relation between thyroid hormone levels and cognitive test scores, school performance, and behaviors: controlling for socioeconomic status

	n	r*	p
T3 vs school examination Scores	28	0.60	0.0008
T3 vs % time "off-task" in Classroom	37	-0.29	0.09
Free T4 vs verbal Meaning test	94	0.20	0.06
Free T4 vs high activity Level in playground	78	0.20	0.07

* Pearson's correlations - 2-tailed - partial conditions

T3 levels were also negatively associated with "off-task" behavior in the classroom and positively related to high activity level in the schoolyard setting. The above relationships persist at near statistically significant levels after controlling for SES.

The Effects of Iron Deficiency Anemia and Height for Age

In addition to low SES, iron deficiency, with or without anemia and stunting, has been shown to have adverse effects upon cognitive function and learning (12).

Both stunting and iron deficiency anemia are present in the schoolers. To demonstrate that iodized salt use and thyroid hormone levels independently influence cognitive function, school performance and behavior outcomes, above and beyond the effects of SES, anemia and height; multiple regression analyses were performed force-entering SES, anemia, size, and then iodized salt use. A parallel analysis was performed with T3, in place of iodized salt (see Table 6.11). T4 and FT4 no longer entered into the equation. However, for school examination scores and Raven's test scores, iodized salt use and T3 each explained a statistically significant portion of the variance in outcomes after SES, hemoglobin, and body size were considered. Thus, schoolers in households which used iodized salt and who had higher T3 levels performed better on school examinations and on Raven's Matrices Tests after controlling for other factors which could also affect these outcomes.

TABLE 6.11.
Relation between Iodized Salt use, T_3 and School Test Scores and Activity levels, controlling for SES, Hemoglobin and Height.

Outcome	Variables	Beta	SE	p	
Av. test score	SES	.25	0.32	.02	Adj R^2=.25
	Hg	.32	3.74	.001	F=7.8
	HAZ*	.13	5.00	.20	p <.001
	Iodized salt use	.18	0.83	.09	
Av. test score	SES	.17	0.75	.36	Adj R^2 =.37
	Hg	.10	8.72	.65	F=4.4
	HAZ	.09	9.38	.62	p <.011
	T_3	.56	0.19	.01	
High activity level in playground	SES	.19	0.00	.10	Adj R^2=.13
	Hg	.11	0.01	.30	F=4.2
	HAZ	.11	0.01	.30	p <.004
	Iodized salt use	.24	0.00	.03	

* HAZ - Height for Age Z-score

Discussion

The mild hypothyroidism observed is most likely related to low intake of iodized salt, low iodine content in the water, soil and food. The goitrogenic effect, particularly of cabbage and probably also *sukuma wiki* (kale) in the diet, were seen to be associated with the marginally elevated levels of TSH and may be an additive factor in further depressing thyroid function.

The lack of association between the presence of goiter and thyroid hormone levels has been seen in other studies. In endemic areas of iodine deficiency, individuals with goiter may be euthyroid and those without goiter may have elevated TSH and/or depressed T3 and T4 levels (10).

In the presence of mild iodine deficiency the school performance, classroom attention and activity level of Embu schoolers are adversely affected. The ability to pay attention in the classroom and to maintain a high activity level in the schoolyard, allowing the child to explore and better interact with the environment and others, are important mechanisms contributing to increased learning and better school performance. These same schoolers showed that "off-task" behavior was negatively related to cognitive test performance and school examination scores in an earlier publication (5) and that low activity level in the playground relates negatively to subsequent cognitive abilities measured three years later (6).

Evidence from several other studies indicate that children born and raised in even mild/moderately iodine deficient areas, are at risk for impairment of cognitive function and decreased school performance, and in some instances growth (13). These children may be euthyroid or hypothyroid and may or may not be goitrous, although thyroid hormone levels were actually measured in only a few of these studies. Thus hypothyroidism may well be grossly under-diagnosed in areas of iodine deficiency (13).

The policy implications of these findings are particularly important where iodine deficiency is mild or moderate. Mild degrees of iodine deficiency may go unnoticed, but may adversely effect the mental and physical development of children. These adverse effects may additionally or synergistically aggravate the poor cognitive development, school performance and poor growth[3] associated with protein energy malnutrition, iron deficiency and other micronutrient deficiencies.

Policies and programs for ensuring universal distribution and use of iodized salt in iodine deficient areas must be implemented through legislation and/or subsidization. Kenya has a policy of iodination of salt but apparently the iodized salt is either inaccessible or families are not aware of its importance.

CONCLUSION

Cognitive function and behavioral outcome in children of all ages are influenced by multiple and interacting factors studied in the Kenya CRSP. These include food intake, nutritional condition of the child, the home environment, home rearing and caretaking

[3] Iodine deficiency also affected stature in the school children, see Chapter 5.

interactions, parental cognitive and educational endowment, and the illness experience of the child. The relative importance of these factors vary with different stages of development. An analytic challenge in these non intervention studies is to be able to control for many interacting factors to be able to tease out significant and meaningful determinants of cognitive function and behavior.

Through the use of multivariate analyses and partial correlations, it was found that mild-moderate malnutrition and chronic energy shortage has deleterious effects on a child's cognitive development and behavior, even when environmental and parental factors are considered. It was also found that dietary quality and total energy intake both have an important influence on the cognitive function of the child. The intake of animal source protein, fat and micronutrients are of particular importance with regard to cognitive function even when controlling for total energy intake, SES and home and environmental factors. Activity level on the other hand is strongly related to concurrent energy intake. Activity level and exploratory behavior are positively linked to learning. This has implications for children who arrive at school poorly fed or not fed.

Animal protein contains the micronutrients zinc and iron in bioavailable form, as well as vitamin B_{12} and is seen to have both short term and long term effects on the child's performance. Fat is a compact source of energy. Total energy and animal protein were important for symbolic play and activity level, both important mediators of cognitive development and learning. Cognitive function in schoolers was predicted by the animal protein and fat intake and calorie intake when the child was age three.

Mild iodine deficiency in the Embu district was determined to have adverse effects on the child's school performance and cognitive tasks, even when controlling for socioeconomic status, anemia and the height of the child. Iodine plays an important role in learning and growth. Unfortunately, iodized salt is used by only a third of the households in Embu.

Another important finding is that stunting and underweight have adverse consequences on cognitive performance. In infancy, for example, the larger the infant the more it smiles and vocalizes and the better its performance is on the Bayley mental scale. Stunted children, including both toddlers and schoolers, do not do as well on cognitive tests as their well grown peers. The stunting remains an important factor even after controlling for rearing and parental factors, environmental conditions and food intake. Thus achieved size, particularly height, is an important predictor of cognitive function.

Morbidity frequently accompanies malnutrition and has adverse effects on cognitive development in toddlers and schoolers. Of particular interest is the effect of mild illness on the schoolers and serious and mild illness on toddlers. In both cases girls seem to be more affected than boys. Controlling for parental influence and home environment illness continues to exert effects on cognitive outcomes. The sick child, particularly the children in general are less active and have less experiential learning through interaction with the environment and people.

Preliminary analyses on the role of anemia on learning and school performance are showing promising results but are not reported here. B_{12} deficiency in infancy is now being analyzed for affects on growth and development.

The above findings have important implication not only for children of developing countries but also for children of poverty and disadvantage in the USA.

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CHAPTER SEVEN.
EFFECT OF REDUCED FOOD INTAKE ON RESTING ENERGY EXPENDITURE IN RURAL KENYAN ADULTS

There is considerable disagreement as to whether or not reduction of resting energy expenditure (REE) is a response to decreased energy intake. Increased efficiency in energy utilization, as expressed by a lowering of REE, has been suggested by Sukhatme and Margen (1). Is one of the adaptations to a lowering of energy intake, a reduction of REE or do other responses, mainly loss of body mass and decreased activity predominate?

Periodic drought and severe reduction or failure of food crops and disruption in food availability is a common occurrence in areas of rain fed subsistence agriculture in sub-saharan Africa. Thus, the opportunity to test the hypothesis that a lowering of REE occurs in response to such a decline in energy intake presented itself. The availability of data on monthly energy intake and anthropometric measurements and quarterly measurements of REE allowed an examination of this hypothesis in the Kenya project.

BACKGROUND

An untoward event, a severe drought associated food shortage and near famine like conditions enveloped the entire study area in Embu Kenya in 1984, as part of the greater Sahelian drought. As ongoing data collection on quantitative food intake, anthropometry and REE was taking place in the drought affected area, this catastrophic event provided the opportunity to study, longitudinally, the effect of acute food shortage on REE in pre-shortage, shortage and post shortage periods. For detailed information on the drought please refer to the chapter on the Impact of Drought.

The REE of adult men and women were studied. The women were further differentiated by their stage of reproduction as described in the chapter on Reproduction. The assignment of the women into non-pregnant non-lactating (NPNL), pregnant and lactating categories allowed us to describe the normal changes in REE in the course of pregnancy and lactation, compared to REE changes by reproductive status during a period of deprivation. As reviewed in the chapter on Reproduction, Embu women in general decrease their intake during pregnancy, and experience poor pregnancy weight and fat gain and even loss late in pregnancy. Postpartum net pregnancy weight gain (predominantly fat storage) is low. In addition, a decrease in physical activity was documented by time allocation studies.

In well nourished women in the United Kingdom and USA increase in REE during pregnancy is as high as 39%, commensurate with growth of the fetal mass, maternal membranes and products of conception, all metabolically active tissue (2). In the five country study of REE and pregnancy, only one country, the Gambia, reported a lowering of REE as a compensatory mechanism for decreased energy intake (3).

METHODS

Data collection occurred before, during and after the food shortage periods, presenting a valuable opportunity to explore the impact of changes in food intake on changes in body size and REE using period analyses. Factors associated with nutritional status and resting energy expenditures, such as prior nutritional and health status, infection and SES, are controlled for by the nature of the within subjects design and use of paired t-tests.

Sample

Two hundred forty-seven (247) adult men, heads of the study households, were observed and tested. Their mean age was 37.7$\pm$ 7.6 (SD) years. These men were usually involved in subsistence and cash crop farming activities, particularly land preparation, planting and harvesting. Some had cash salaried jobs as farm laborers or carpenters.

One hundred thirty-eight (138) women who became pregnant during the study and were followed to six months postpartum participated in the REE study. The mean age of the women was 32.0$\pm$5.8 (SD) years. Reproductive status was designated as pregnant, lactating or non- pregnant non-lactating (NPNL, also referred to as pre-pregnant).

Description of Nutritional and Food REE Measures

For the purpose of data analysis, average daily energy intake (kcal/day and kcal/kg/day) are reported for four intervals: pre-shortage: March- May 1984; Shortage: September-November 1984; early post shortage: January-March 1985 and late post shortage: April-June, 1985. The late post shortage period is included because recovery from the drought was gradual over 1985 and provided an opportunity to compare drought vs. non drought times during the same months of the year and to observe any seasonal trends in a "normal" year (1985). Mean kcal intake is reported as the mean of all monthly values per period.

Height was measured to the nearest 0.1 cm by a measuring device a "nivotoise", which has a horizontal foot and head plate. Weight was measured monthly using a portable, battery-operated, digital read-out scale. Two trained examiners working independently obtained the measurements. If the values were discrepant by more than a predetermined amount, both examiners repeated their measurements and the mean of the four measurements was recorded. Average z-scores for weight, height and weight/height for each subject were calculated based on Metropolitan Life - WHO reference data (4). Body fat was assessed by use of fat folds (triceps, biceps, subscapular) and by use of the Durnin equation (5). Arm muscle area (AMA) and total muscle mass (TMM) were assessed using a nomogram (6) and body weight and fat.

Statistical Methods

The major statistical methods used for analysis are paired t-tests with subjects serving as their own controls and repeated measures ANOVAs (7). Comparisons were made between the pre-shortage and shortage period, and the shortage period and post shortage periods.

Resting Energy Expenditure

With the exception of a few preliminary REE tests during January 1984, the data were collected from February 1984 through September 1986. The same methodology was used for male and female subjects. The Beckman Metabolic Measuring Cart (MMC), was used to measure REE. The MMC is an automated and mobile system for assessing metabolic, respiratory, and ventilatory parameters. The unit contains a series of analyzers for measuring CO_2, O_2, expired volume, temperature, barometric pressure and time. The MMC uses magnetic cards to program a processor which controls the timing and sequence of measurements. The MMC was powered by a diesel generator as there was no source of electricity. A pilot study was invaluable in helping to identify logistical problems and in providing information on how subjects reacted to the test situation. A more detailed description of the MMC's specifications is available in the 1987 Kenya Project Final Report.

Techniques of Data Collection

As stated above, resting energy expenditure data were collected over a two year period starting in February 1984. On the average, each subject was scheduled for a REE study every three months. During pregnancy REE tests were performed at 1, 5 and 8 months of pregnancy and during lactation at 1, 3 and 6 months postpartum.

The REE test procedure was as follows. On the day prior to the examination, the household member to be tested was alerted that a test had been scheduled for the following morning and the subject requested not to eat or smoke for at least two hours prior to the test (most people had fasted since the previous evening meal). On the morning of the examination day, a project vehicle transported respondents to the REE laboratory at 7 or 8 am. Upon arrival height, weight and age were obtained by a project nurse and then subjects rested in a quiet area near the clinical laboratory. As space became available, the subjects were escorted to the REE laboratory, positioned on the REE test table and fitted with a face mask, but not connected to the Beckman MMC. The subject then rested for 30 minutes in a supine position with the face mask in place to become accustomed to breathing while wearing the mask.

The technician recalibrated the MMC's O_2 and CO_2 sensors and conducted a quick status check of the machine's operating parameters. Once the technician was assured that the machine was operating correctly, the respondent's tubing was connected to the MMC. The subject's age, sex, height and weight; and room temperature, barometric pressure and humidity were entered into the MMC processor.

The Beckman Nutritional Program performs a range of calculations automatically and also allows for modification by the technician. The technician collected minute by minute respiratory/metabolic data. One of two calculation procedures were used depending on whether or not the respondent achieved steady-state rest conditions during the test. If a steady state was reached, the computed values for VE, VO_2 and VCO_2 were averaged from the data of the three measurement intervals. If no steady state was reached during the 10-minute test period, the summary calculations were performed based on the last data set (e.g. minute 10). The respondent's resting energy expenditure (REE) (kcal/day), REE/body weight (kcal/kg), REE/body surface (kcal/m^2), and REE/PRE (Predicted REE) were then calculated. At the beginning of each-10 minute test segment, the fraction of inspired oxygen (FIO_2) in ambient air was calculated. Pilot testing showed that the minute by minute respiratory/metabolic values stabilized after the first 10 minutes of testing. Therefore, it was decided that three representative minutes from the second and third 10-minute test segments would be recorded for computer analysis. Minutes 18, 19, and 20 comprised the *First Period*, while minutes 28, 29, and 30 constituted the *Second Period.*

Due to a faulty CO_2 analyzer for over a three month period, both the VCO_2 and the RQ values produced by the MMC during this period were spurious. Thus a default RQ value of .85 was used to correct the VCO_2. Both the RQ value of .85 and the corrected VCO_2 values were computer-entered. The default value of .85 was based on the average of previously obtained RQ's.

Quality Control Procedures

The quality control of the REE measurements was supervised by the senior investigator and by senior field staff. The laboratory was visited regularly, forms were reviewed for completeness and tests were observed to ensure adherence to protocol. Particular emphasis was given to verifying that masks were regularly checked for leakage. Also, log books were maintained to record MMC calibration levels (the quality of the calibration gases purchased was monitored throughout the study by comparing them with known percentages of gas in cylinders provided by Beckman) and servicing dates.

To check for MMC reliability, selected Project field staff were tested on a regular basis. From June until November 1985, four senior staff members were tested for REE on two consecutive days per month. The REE quality control tests on staff followed the identical protocol used during respondent testing. For REE kcal/day within person the comparisons yielded mean correlation coefficients of .74 and for REE kcal/kg/day a correlation coefficient of .84. The mean difference in REE derived from these control tests is 96 kcal/day and on a per weight basis, the mean difference is 0.8 kcal/kg/day.

FINDINGS

Adult Males

Findings are presented by cross-sectional and paired analysis which accounts for slightly different values for some of the changes seen in energy intake, weight and REE.

Energy Intake

Energy Intake of the male adults are presented by means and standard deviations (SD) for the pre-shortage, shortage, and early and late post shortage periods. The mean kcal intake decrease during the shortage period was approximately 400 kcal per day (see Table 7.1).

TABLE 7.1.
Energy intake in Lead Males in pre-food shortage, shortage and post-shortage periods (cross-sectional analyses)

	Pre-Shortage n=95	Shortage n=130	Post 1 n=137	Post 2 n=103
Energy Intake kcal/d	2054±579	1609±526	2033±575	1951±1570
kcal/kg/d	38.5±13.2	29.2±12.3	38.7±14.5	37.0±15.1

Paired analyses of kcal intake during pre-food shortage periods and food shortage and post-shortage periods are presented in Table 7.2 and Figure 7.1. Statistically significant differences are seen between the pre-shortage and shortage periods and the shortage and post-shortage periods.

TABLE 7.2.
Paired analyses of adult male food intake during pre-shortage, shortage and post shortage periods.

	n	t	p	Mean Difference
Pre-shortage vs. Shortage				
kcal/d	52	3.77	.0009	-554
kcal/kg/d	52	3.26	.003	-9.3
Post shortage vs. Shortage				
kcal/d	77	4.50	.0001	433
kcal/kg/d	77	4.11	.0001	7.1
Pre-shortage vs. Post shortage				
kcal/d	52	0.62	.54	83.9
kcal/kg/d	52	0.62	.54	1.5

Anthropometry

Changes in body dimensions are summarized in Table 7.3 and Figure 7.2.

TABLE 7.3.
Anthropometry in lead males in pre-food shortage, shortage and post shortage periods (cross-sectional analyses)

	Pre-shortage	Shortage	Post 1	Post 2(late)
	n=95	n=130	n=137	n=105
Weight	55.1±6.5 (42.0-77.4)	53.3±6.5 (38.0-70.0)	54.6±64 (40.4-74.1)	55.5±7.1 (38.8-75.8)
	n=62	n=97	n=106	n=96
Fat				
Sum* Fat folds (mm)	19.3±9.7	15.3±4.7	17.0±5.7	17.5±5.7
% Body Fat†	10.3±4.8	8.2±3.4	9.4±3.3	9.7±3.1
Muscle				
Tot. Muscle Mass (cm^3)	20.1±3.4	20.3±3.3	20.6±36	21.4±3.7
Arm Muscle Area‡ (cm^2)	33.6±6.1	33.7±6.7	34.4±6.9	35.9±7.2

* Sum 3 fat folds: triceps, biceps, subscapular
† Based on Durnin's equation
‡ Jelliffe and Jelliffe, 1991

Weight Changes

In general, the men were generally shorter and lighter than a Nairobi sample and other Kenyan counterparts (9) and well below reference levels used by WHO (adapted from 1959 Metropolitan Reference Data)(5). The mean z-score for weight is -1.6 ± 0.4 (SD) and the mean z-score for height is -1.5 ± 0.8 (SD).

Weight in the pre-shortage to shortage period decreased by a mean of about 2 kg with restoration of body weight in the post shortage periods (see Table 7.4). These changes in weight are statistically significant.

TABLE 7.4.
Body weight, fat and muscle paired t-tests for pre-shortage, shortage, post shortage periods

	n	t	p	Mean difference
Pre-shortage vs. shortage				
Weight (kg)	56	6.96	.0001	-2.04
Fat, sum 3 fat folds (mm)	31	2.57	.0154	-1.31
Percent body fat	31	2.57	.0154	-1.31
Muscle, arm muscle area (cm^2)	31	0.79	.434	-0.53
Total muscle mass (cm^3)	31	0.84	.407	-0.27
Post shortage vs. shortage				
Weight	61	7.66	.0001	2.35
Fat, sum 3 fat folds (mm)	46	5.14	.0001	2.04

Body Fat Changes

Body fat decreased during the food shortage period by 2% compared to pre and post-shortage periods. Paired analyses of the three periods show a statistically significant decrease during the food shortage and then an increase to pre-shortage levels (see Table 7.4).

Muscle Mass Change

Arm muscle circumference and muscle area were used to assess changes in muscle mass. No decreases during the food shortage period were noted (see Table 7.4). TMM and AMA increased slightly in the post shortage periods, but these changes were not significant.

REE Changes

REE kcal/kg/day and REE kcal/day are shown in Table 7.5.

TABLE 7.5.
Resting energy expenditure in men (cross-sectional analyses)

	Pre-shortage	Shortage	Post Shortage
	n=95 mean ± SD	n=130 mean ± SD	n=137 mean ± SD
REE kcal/day	1297 165	1271 208	1277 208
REE kcal/kg/day	33.3 2.7	23.9 2.8	23.5 3.8

Paired analyses indicate no appreciable difference in the REE kcal/day during the food shortage period compared to the other periods. Differences were not statistically significant except for a slight difference in the shortage vs. late recovery periods. When REE kcal/kg/day was examined in the three periods no significant change was seen from one period to another (see Table 7.6 and Figures 7.3 and 7.4).

TABLE 7.6
Resting energy expenditure in Embu men: Paired t-tests for pre-shortage, shortage and post shortage periods

	n	t	p	Difference in kcal/d and kcal/kg/d
Pre-shortage vs shortage				
REE kcal/d	56	-0.18	NS	-30.0
REE kcal/kg/d	56	-1.95	NS	-00.9
Post shortage 1 vs shortage				
REE kcal/d	79	0.98	NS	20.0
REE kcal/kg/d	79	-0.54	NS	-00.21
Post shortage 2 vs shortage				
REE kcal/d	61	4.02	.0002	88.8
REE kcal/kg/d	61	1.43	NS	00.6

Thus, the drought-associated food shortage strongly affected energy intake, body weight, and fat stores but total REE kcal/d to only a slight degree. Negligible differences were seen in REE kcal per kg per day from one period to another.

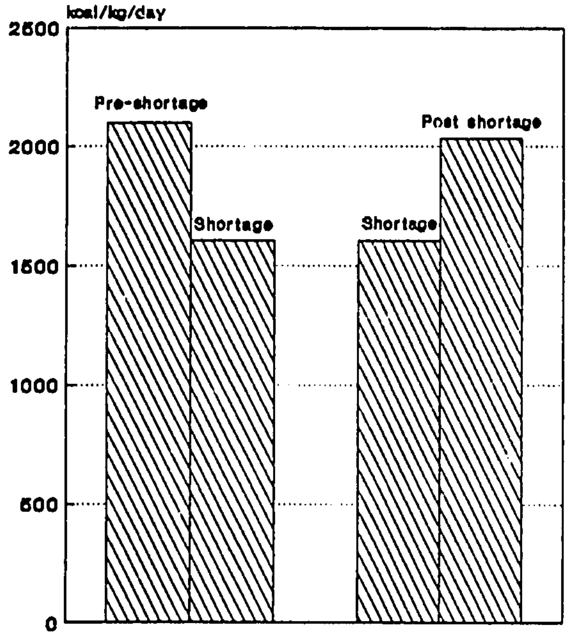

Fig. 7.1: Comparison of energy intake of adult males before, during and after food shortage

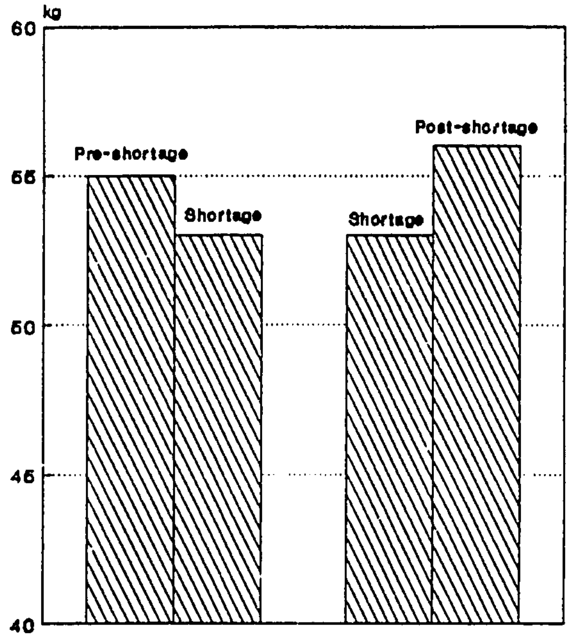

Fig. 7.2: Comparison of body weight for adult males before, during and after food shortage

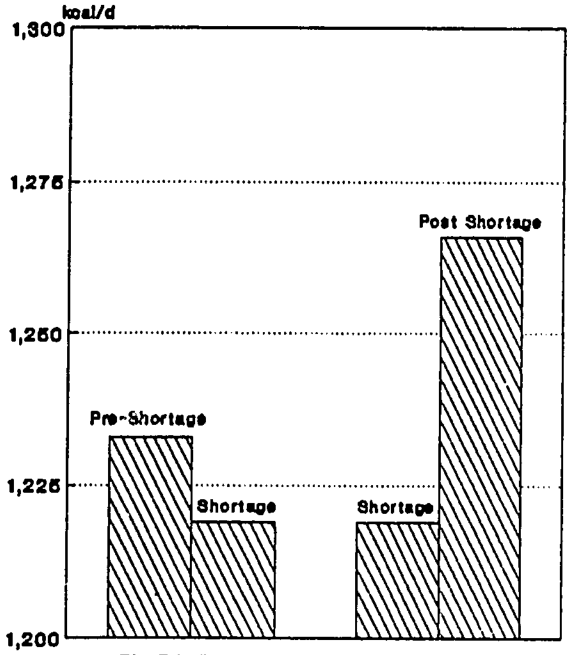

Fig. 7.3: Comparison of REE for adult males before, during and after food shortage

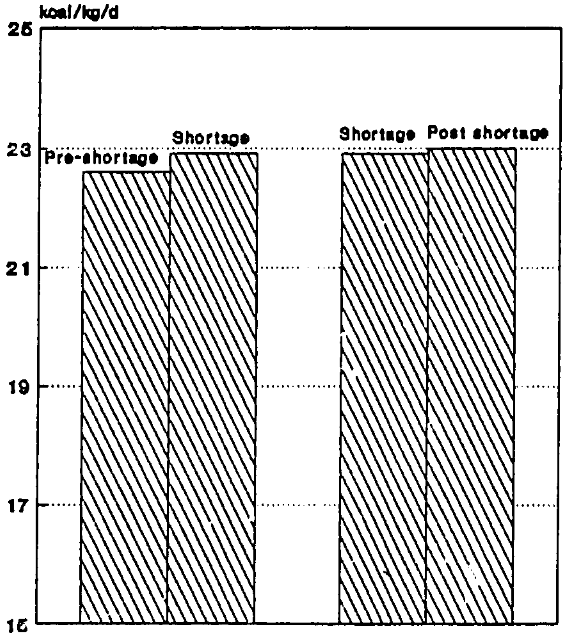

Fig. 7.4: Comparison of REE for adult males before, during and after food shortage

Relationship of REE to Nutritional Status Indicators

ANOVA's between REE kcal/day, REE kcal/kg/day and energy intake, body weight, fat and muscle were calculated to seek relationships of REE to nutritional status. Energy intake per day or per kg showed no relationship to REE. However, body weight, lean body mass (e.g., arm muscle area and total muscle mass) and to a lesser extent height show significant relationships with REE kcal per day and REE kcal per kg (see Table 7.7). The relationship of REE to the Body Mass Index is even stronger than with height and with weight.

TABLE 7.7
Relation between resting energy expenditure and nutritional variables in adult males (regression analyses df=1)

			Adj R^2	F value	p
REE kcal/d	vs	Height	.02	14.3	.002
		Weight	.22	175.0	.0001
		% fat	.01	5.3	.02
		Total muscle mass	.18	105.0	.0001
		Arm muscle area	.15	89.0	.001
		Energy intake			
		kcal/d	.006	.84	NS
		kcal/kg/d	.009	.21	NS

Thus, small differences in total daily REE is in response to changes in body weight rather than to changes in energy intake. In addition, a decrease in physical activity was noted during the food shortage period, but not documented. Normal agricultural tasks were suspended and people were foraging for food, looking for paid employment or sitting idle.

In summary, the main compensatory response to decreased energy intake appears to be loss of body weight and fat rather than a substantial "downward adjustment" of resting energy expenditure. These changes may be detrimental to the health and productivity of the individual.

Pregnant and Lactating Women

Energy intake and changes in weight, fat and muscle are thoroughly reviewed in the chapter on Reproduction.

Energy Intake

Despite increasing energy needs during pregnancy, the women's energy intake decreased with each ensuing trimester of pregnancy. This was further accentuated by the drought associated food shortage, which affected about a third of the sample. The mean overall pregnancy intake was 1466 kcals per day and energy intake increased in lactation to pre-pregnancy levels, about 1770 to 1800 kcals/day in the first 6 months of lactation. Third trimester intake was 1140 kcal/d during the drought and 1500 kcal/d in the non drought period, one year later. See chapter on Reproduction for detailed information on food intake during pregnancy and lactation.

Pregnancy Weight Gain

Relevant to the REE studies, the mean total pregnancy weight gain was 6.3 ± 3.4 kg. Loss of body fat, muscle mass and even body weight was characteristic in the last months of pregnancy. Net postpartum (pp) weight gain was 1.5 kg (pre-pregnancy weight compared to weight obtained 3-10 days postpartum), in contrast to the 3 to 3.5 kg gained in well nourished women in the UK and USA (2).

Mean pre-pregnancy values for body size were a BMI of 21, weight of 50 kg, and a height of 154 cm. Body composition and weight changes are presented in detail in the chapter on Reproduction.

Resting Energy Expenditures in Different Stages of Pregnancy and Lactation

Pre-pregnancy and first trimester pregnancy values for REE were found to be similar- 1114 compared to 1116 kcal/day. REE increased to 1267 ± 195 (SD) kcals per day at eight months of pregnancy, a 14.9% increase, compatible with the increase in pregnancy REE found in a five country study (3). This rise is in contrast to a mean increase of 39% in REE in women in the USA who are well nourished, and an overall 27% rise in women of industrialized countries (9). In lactation, REE values return gradually to near pre-pregnancy levels. On a per weight basis, REE kcal/kg/day remains fairly constant in pre-pregnancy, pregnancy and lactation with values ranging from 23.1 to 24.0 kcal/kg/day (see Table 7.8, Figure 7.5).

TABLE 7.8
Mean energy intake and resting energy expenditure in different stages of lactation and pregnancy of the REE sample (cross-sectional analyses)

Period	n	Kcal intake/d	REE kcal/d	REE/kcal/kg/d
		mean±SD	mean±SD	mean±SD
Pre-preguancy	21	1851±587	1114±158	23.8±3.0
Pregnancy (by trim)				
First	19	1590±492	1116±158	23.1±4.3
Second	63	1488±492	1236±201	23.5±3.9
Third	74	1351±475	1280±180	23.7±3.2
Lactation (by period)				
First (0-45 days)	75	1830±729	1209±183	24.0±3.8
Second (46-135 days)	92	1791±488	1185±192	23.3±4.0
Third (136-180 days)	15	1771±529	1151±152	23.6±4.3

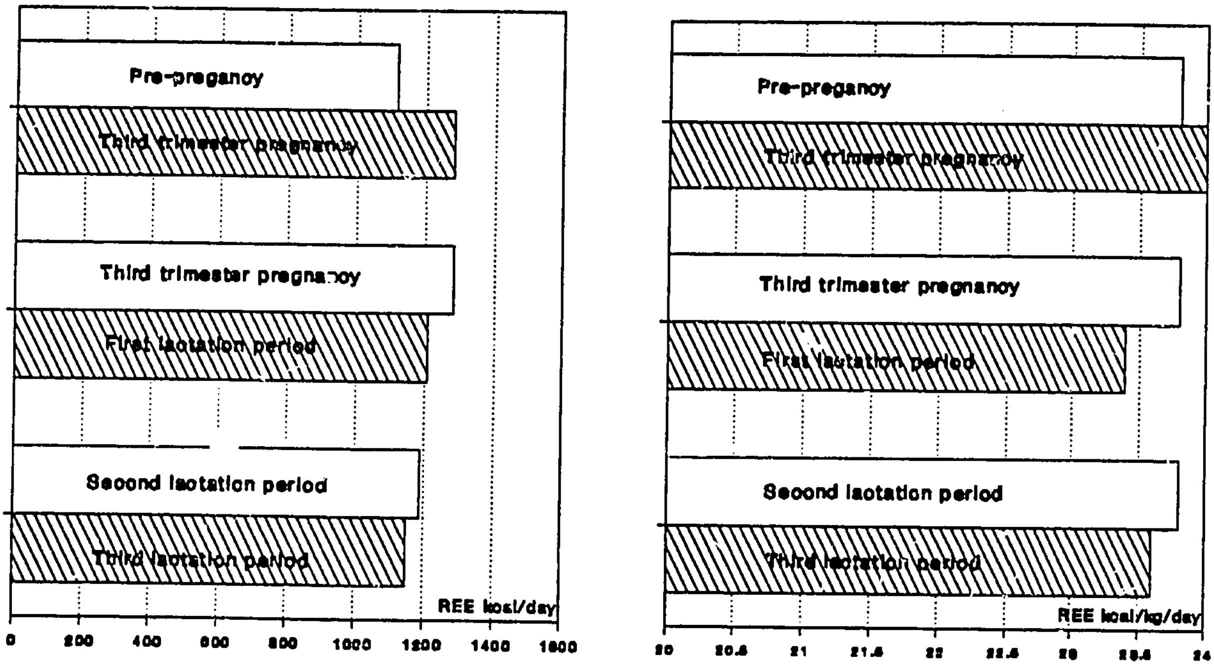

FIG 7.5: Resting energy expenditure between various pregnancy and lactational periods (longitudinal sample)

First trimester: 0 to 90 days
Second trimester: 91 to 180 days
Third trimester: 181 days until delivery

First lactation period: 0 to 45 days
Second lactation period: 46 to 135 days
Third lactation period: 136 to 180 days

Behavior of REE by Reproductive Stage in Relation to Food Shortage

Resting energy expenditure (REE) was examined, not only by reproductive status, but also in relation to the food shortage (see Table 7.9).

TABLE 7.9.
REE (kcal/day mean±SD) in lead females by reproductive stage and in relation to food shortage

Pregnancy status	Pre-shortage			Shortage			Post shortage		
	n	mean±SD		n	mean±SD		n	mean±SD	
Non pregnant non lactating	117	1117	183	87	1141	185	119	1226	204
Pregnant*	63	1216	163	31	1267	217	28	1337	184
Lactating	32	1191	170	69	1128	152	90	1195	180

REE(kcal/kg/day, mean ± SD)

Pregnancy status	Pre-shortage		Shortage		Post shortage	
	mean ± SD		mean ± SD		mean ± SD	
Non pregnant non lactating	23.4	4.0	23.2	3.9	24.5	3.6
Pregnant†	24.0	3.3	23.3	2.9	23.5	3.7
Lactating	22.8	3.1	23.4	3.8	24.5	2.9

	Trim. 1	Trim. 2	Trim. 3
* kcal/d	1126 .21	1216 183	1265 182
† kcal/kg/d	22.8 3.4	22.9 3.2	23.5 3.8

Differences in REE (kcal/day) were found from the shortage to post shortage periods in NPNL and in lactating women and from the pre-shortage to post shortage period in pregnant women. These latter differences may have been due to food relief that mothers still received in the post shortage pericd, resulting in an actual increase in food intake and weight gain. This idea is supported by the slight weight gain observed in the adult men in the post shortage period.

When REE was considered on a per kg basis then no significant change is seen associated with either reproductive stage or in relation to the food shortage period.

ANOVA and paired t-test (Tukey) analyses were used to detect differences from pre-shortage to shortage and post shortage periods by stage of reproduction (see Table 7.10).

TABLE 7.10.
Paired analyses of REE (kcal/day and kcal/kg/day) by reproductive status and relation to food shortage*

Pregnancy status	Groups showing statistically significant differences in REE	
	REE (kcal/d)	REE (kcal/kg/d)
Non pregnant non lactating	Shortage-Post shortage	none
Pregnant	Pre-shortage-Post shortage	none
Lactating	Shortage-Post shortage	none
Food shortage period	**Groups showing statistically significant differences in REE**	
	REE (kcal/d)	REE (kcal/kg/d)
Pre-shortage	none	none
Shortage	Pregnant-NPNL	none
	Pregnant-Lactating	none
Post shortage	Pregnant-NPNL	none
	Pregnant-Lactating	none

* Results of ANOVA and Tukey t-test at alpha =.05

In examining REE by the period of the food shortage according to the stage of reproduction, it was found that during the food shortage period the mean REE values increased significantly in pregnant women compared to NPNL women followed by a significant decrease in mean REE in the lactating women compared to the pregnant women. These changes are the same as those found in the non-shortage period. In the post shortage period similar decreases in REE are seen from the NPNL state to pregnancy and from pregnancy to lactation. As in the unstratified analysis, when REE on a weight basis, kcal/kg/day was examined, no appreciable changes were found in REE associated with the stage of pregnancy or food shortage period.

In summary, despite the severe food shortage, the normal progression of changes in REE (kcal/day) is seen. There is a small increase in REE (kcal/day) in pregnancy, then a gradual decrease to NPNL levels in lactation not directly related to food intake. Resting energy expenditure, on a per weight basis, showed no appreciable change either by reproductive stage or in relationship to food intake either in the course of pregnancy or with the food shortage.

Determinants of REE

Resting energy expenditure shows consistently positive relationships with long term and more current indicators of body size and composition. This was demonstrated through use of Pearson's correlations (2-tailed) and multivariate regressions (see Table 7.11). The correlations are similar in pregnancy, lactation or in NPNL status. REE is seen to decline with increasing age. Also, the lower the REE, the more thyroid stimulating hormone is elevated, as has been shown in the Food Intake chapter. (Mild iodine deficiency is present in the area).

As with the findings in the men, energy intake, whether expressed as kcal/day or kcal/kg/d, obtained within each 3 month period in which REE was studied, shows weak or no significant associations with REE.

TABLE 7.11.
Relationship between resting energy expenditure (kcal/d) and nutrition parameters

	NPNL n=178	Pregnancy n=136	Lactation
Height	.37	.39	.33
Head Circ.	.25	.24	NS
Weight	.50	.41	.58
BMI	.32	.22	.34
MUAC	.29	.20	.31
% Fat	.21	.20	.20
Muscle Mass	.37	.24	.31
Kcal/d intake	.13	NS	.15
Kcal/kg intake	NS	NS	NS
Maternal age	NS	-.28	-.16
TSH	-.14	NS	NS

Pearson's correlations (2-tailed) p <.05 to .0001

Multiple regression analyses were used for prediction of REE in pregnancy and lactation. Variables included maternal age, percent body fat, total muscle mass (TMM), kcal intake, BMI and birth weight (see Table 7.12).

Significant factors predicting REE during pregnancy are body size, muscle mass (lean body mass), BMI, birth weight (all positive), and maternal age (negative); but energy intake and percent body fat did not contribute significantly to the equation. During lactation only weight and age were significant components in the equation.

TABLE 7.12.
Determinants of REE in pregnant and lactating women

Pregnancy: N=88

Variable	Parameter Estimate	Standard Error	t	p	Standard Estimate
Intercept	675.8	214.5	3.1	0.002	0.00
Age	-8.1	3.2	-2.5	0.014	-0.26
Kcal/day	-0.0	0.0	-0.1	0.868	-0.01
Muscle mass	17.5	7.7	2.2	0.027	0.24
Pct fat	-6.8	4.7	-1.4	0.158	-0.20
Weight	108.9	39.5	2.7	0.007	0.27
BMI	176626	107429.0	1.6	0.104	0.24

R^2=.25 adj R^2=.23
F=5.3, prob >F .0001
df=5

Lactation: N=132

Variable	Parameter Estimate	Standard Error	t	p	Standard Estimate
Intercept	786.9	139.2	5.6	0.000	0.00
Weight	14.2	3.9	3.6	0.000	0.63
Age	-5.4	2.2	-2.4	0.017	-0.19
Kcal/day	0.0	0.0	0.5	0.609	0.04
Muscle mass	-2.8	7.2	-0.3	0.693	-0.04
Pct fat	-5.4	4.0	-1.3	0.181	-0.17
Bweight	-6.8	29.7	-0.2	0.817	-0.01
BMI	5705.2	111095.0	0.1	0.959	0.00

R^2 = .25 adj R^2 = .21
F=6.8, prob>F .0001
df=6

Reduction in Activity

As described in the 1987 Final Report and in the chapter on Reproductive Function, pregnant women were found, by time allocation studies, to double their inactive time, particularly in the third trimester of pregnancy and in the first six weeks of lactation. Women accomplish this by greatly reducing the amount of time they spend caring for others and themselves and on farm activities. It was also shown that during illness, pregnant women reassign their usual tasks to others and/or receive a considerable amount of help with their daily tasks. See chapters on Morbidity and Time Allocation for more details.

Activity Energy Expenditure

A study of activity energy expenditure on a small sub-sample of eight men and seven women examined if people on chronically reduced energy intakes work more efficiently or at low energy expenditures per task than better fed people (see 1987 Kenya Nutrition CRSP Final Report). A Max Plank respirometer was used which continuously monitored oxygen consumption and thus energy expenditure during the performance of usual daily activities. These included washing, cooking, chopping wood, various agricultural tasks such as planting, weeding, picking coffee etc. and sitting, lying, standing. Also walking unloaded and with various loads (5-25 kg) was included. Oxygen was measured by a Teledyne oxygen analyser and the Wier formula was used to relate oxygen consumption to kcals of energy expended (1L O_2 =4.92 kcal).

The mean adult expenditure for men and women are shown in Table 7.13. These values closely agree with values reported in the literature (10). Therefore there is no evidence that people chronically ingesting energy poor diets work more efficiently on lower intakes than those better fed.

TABLE 7.13.
Mean adult expenditure values for representative Embu activities (kcal/min)

	Males (n=8)			Females (n=7)		
Activity	Mean kcal	Mean SD	Mean kcal/wt	Mean kcal	Mean SD	Mean kcal/wt
Lying	0.91	0.13	0.02	1.06	0.18	0.00
Sitting	1.11	0.09	0.02	1.08	0.19	0.02
Standing	1.07	0.15	0.01	1.04	0.13	0.02
Washing	2.95	0.50	0.05	2.98	0.60	0.05
Cooking	--	--	--	1.87	0.48	0.04
Weed/panga	4.31	0.63	0.08	4.27	0.78	0.08
Weed/hoe	5.43	1.51	0.10	4.76	0.97	0.09
Pick coffee	1.92	0.48	0.04	1.66	0.35	0.03
Harv maize	2.68	0.56	0.05	2.53	0.35	0.05
Harv beans	3.75	0.48	0.07	3.05	0.53	0.06
Thresh beans	5.78	0.89	0.10	5.15	1.03	0.10
Chop wood	5.43	1.16	0.10	4.50	0.79	0.09
Walk	3.51	0.45	0.07	3.61	0.77	0.07
Walk 5 kg	--	--	--	3.47	0.53	0.07
Walk 10 kg	--	--	--	3.33	0.55	0.07
Walk 25 kg	--	--	--	3.68	0.86	0.07

CONCLUSION

The analyses of resting energy expenditure on a body weight basis (kcal/kg/d) indicate that in the face of decreased energy intake there is no "metabolic adjustment" as lowering of REE. Changes in REE occur in response to changes in body weight or mass rather than to energy intake per se. This is seen in the men as well as in the women studied in the CRSP.

The main response to decreased energy intake in pregnant women is poor pregnancy weight gain and fat gain, with loss of body fat, weight and even muscle mass late in pregnancy. Decreased physical activity in pregnancy and early lactation is an additional compensatory mechanism to conserve energy. During lactation, on a per kg basis there is also no change in REE. Despite the food shortage, the pattern of REE kcal/d changes according to the reproductive stage were maintained. When REE was considered on a body weight basis, (kcal/kg/d) no appreciable changes were seen. Also based on a small activity expenditure study, the subjects do not work at an increased efficiency using less energy per task performed.

The above findings have policy implications for health and productivity for adults in developing countries. These populations, as in Embu, live not only with uncertain food supplies and chronic undernutrition, but are subject to superimposed periodic severe food shortages. Assurance of an adequate and stable food supply is needed to conserve body mass and normal levels of activity. For malnourished women who enter childbearing and experience inadequate food intake, poor pregnancy weight gain and loss of body mass to support fetal growth, there may also be impaired ability to lactate adequately to support the growth of their infants and a likelihood that they will to become depleted themselves.

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CHAPTER EIGHT.
TIME ALLOCATION STUDIES

An extensive time allocation study based upon the technique of "random-spot observations" (1) yielded highly accurate data on how the members of 169 households spent their time from March 1985 through February 1986. This chapter summarizes a number of papers analyzing the associations between time use and various nutritional indicators. Each section is drawn from the main reference noted, unless otherwise indicated.

RESEARCH OBJECTIVES (2)

As stated in the 1987 Final Report, the objective of time allocation studies was to collect data capable of describing how Nutrition CRSP respondents and other household members spent their time. It was anticipated that such data would be useful for addressing a wide variety of research topics and hypotheses, particularly those relating activities to levels of food consumption. Questions such as the following are immediately amenable to analysis using the Kenya time allocation data:

1. Do households which enjoy higher levels of intake of energy, fat, protein, or other nutrients spend more time producing food and/or cash crops?

2. Do households with relatively good diets exhibit high levels of parent-child interaction and child care?

3. Do adults or children with relatively low caloric consumption spend less time engaged in physical activity than others?

4. Do women spend more time than men performing activities typically targeted by development agencies?

5. Is it more efficient to produce certain crops than others (measured, for example, by energy output per time input)?

6. How do pregnancy, lactation and motherhood affect women's economic productivity?

In short, the time allocation data are widely applicable to numerous research topics or problems. It is anticipated that the data will prove invaluable for a comprehensive understanding of the functional consequences of marginal or moderate malnutrition in the Kenyan study area.

METHODS (2)

The spot observations technique involves visiting households unannounced and observing the behavior of all individuals at the instant of arrival. The activity of each individual is recorded, and each recorded activity represents a single "spot observation." Upon acquiring an adequate sample of observations, the time devoted to each activity can be calculated for specific households, selected categories of individuals (e.g., "adult males"), or even for particular individuals.

The spot observations technique offers a number of advantages over other time allocation techniques (e.g., recall, continuous observation, diary). Among its advantages are: 1) the technique is highly efficient for data collection (considerable data may be collected with relatively little effort); 2) the data are based on observation in most instances, rather than on recall which presumably is less reliable; 3) the technique does not influence observed behavior, since the recorded behavior is limited to that which is being performed at the instant of the investigator's arrival (respondents do not know when they will be visited) and 4) the data are readily amendable for computer key entry and analysis. A potential disadvantage is that households may not welcome investigators for such a purpose: This, however, proved not to be the case in the current study.

This technique normally dictates that households be visited in a random order, but due to the large study area of the Kenya CRSP project, a technique involving a fixed route through the study area was deemed most appropriate to minimize travel time. Bicycles were used to further cut travel time. Household visits were made by one field worker at a time. On the first day of the study, the first household on the route was visited at 7:00 am by the field worker scheduled for that day's morning shift. Proceeding to each subsequent household along the route, he was replaced at approximately 12:30 pm by the field worker assigned to the afternoon shift. Because the afternoon field worker could only approximate the general area where he would meet the morning field worker, they carried walkie-talkies to facilitate their rendezvous at a specific location along the route. The afternoon field worker continued along the route and made the final visit of the day by 6:00 pm. The next household along the route was visited the next day at 7:00 am, and upon reaching the end of the route, a field worker returned to the first household of the route. Over the year, each household was visited 64 times.

It would appear that following a fixed route would be at the expense of losing complete randomness over the order in which households were visited. Yet it must be stressed that a variety of factors; including weather conditions, road and path conditions, and length of visits, all combined to randomize the times when households were visited. That is, the total time required to complete the entire length of the route varied, and as a consequence no household was consistently visited at the same time of day or on the same day of the week. Most importantly, households could not predict when they would be visited.

Because households preferred not to be visited on Sundays or in the evenings, a compromise was reached in which they agreed that visits could be conducted on one Sunday each month, and one evening every other week. All activity descriptions were coded and a computer entry company in Nairobi entered the data with 100% verification.

A brief description of the general procedure for interpreting spot observational data is useful. Basically, the amount of time assigned to an individual or category of individuals (e.g., adult males, households of "low" nutritional status, etc.) for any given activity is based upon the ratio of cases in which that activity was observed to the total number of observations made of that individual or category of individuals. The most basic assumption made in calculating the time spent in each activity is that the proportion of observed cases for each activity is equivalent to the proportion of time spent at them during the sampling period. For example, if "adult males" were observed to be "sitting idle" in 1,000 cases out of 10,000 observations made between the hours of 7:00 am and 9:00 pm, it may be estimated that these individuals spent 10% of their daylight and evening time sitting idle. Thus, to describe how much time a given individual or category of individuals spent at each activity, frequency distributions of all activity observations are calculated and the frequency of each activity is converted to a percentage of total time. In the example above, "sitting idle" would account for 10% of 840 minutes (7:00 am to 9:00 pm), or 84 minutes per day. Descriptions of the activity categories used are found in Table 8.1.

TABLE 8.1.
The 16 time allocation activity categories

Activity Category	Description
Animal Care	Feeding, tending and herding food and draft animals
Ceremony	Ceremonial, religious and political activities
Child Care	All care of a child including holding, breast feeding, feeding, medical treatment, washing, and dressing
Commercial	Cash cropping, manufacturing for sale, shopping, buying, selling, and wage labor
Eating	Eating and drinking
Education	Acquiring and teaching formal education

Food preparation	Cooking, handling, and serving food, and processing food for storage
Grooming	Self-grooming, dressing, and hygiene
Housework	Housekeeping and cleaning, and fetching and managing household water and fuel supplies
Idle due to illness	Doing nothing or sleeping because of illness, and obtaining health care
Inactive	Doing nothing and resting
Manufacture	Making or repairing artifacts, clothes and facilities, and acquiring materials for these purposes
Recreation	Participating in or observing recreation and entertainment
Socializing	Visiting or chatting with others, and caring for or receiving care from another adult
Subsistence Agriculture	Production of food crops (primarily for household consumption)
Wild Foods	Hunting, fowling, fishing, and collecting wild plant foods

Baksh, Neumann, Paolisso, Trostle, Jansen (unpublished observations)

AGRICULTURE STUDY(3)

Of the 169 households studied by the random spot observation techniques between March 1985 through February 1986, 42 households were targeted for the intensive agriculture study. Data on these 42 households are reported in the following sections. The time allocated to general activity categories by Embu adults in the 42 household sample is illustrated in Table 8.2. Food production and cash labor, which may include agricultural activities, clearly account for a significant proportion of both the average man's and average woman's day.

TABLE 8.2.
Time Allocated to General Activities by Embu Adults (18 years and above) of the 42-Household Agriculture Study Sample, from 7:00 am to 9:00 pm (March 1985 to February 1986)

	Minutes/Day	
General Activity	Average Man	Average Woman
Eating	56	41
Food Preparation	9	111
Care of Self/Others	49	149
Household Labor	30	116
Food Production	133	143
Cash Labor	213	51
Inactive	115	73
Education	21	44
Recreation	39	<1
Social	143	88
Other	31	24
Total	839*	840

Baksh, Paolisso, 1987.
* Total does not equal 840 minutes due to rounding.

Time Allocated to Subsistence Agriculture

The amount of time devoted to all subsistence agriculture and other food production is presented in Table 8.3. For both the average man and women, this comprised the majority of all time devoted to food production. The average Embu man spent 80 minutes per day, and the average woman spent 121 minutes per day, engaged in subsistence agricultural activities. Because there are 1.33 men and 1.38 women (18 years and older) in the average household, the average household spent a total of 273 adult minutes per day at subsistence agriculture (men, 106 minutes; women, 167 minutes).

TABLE 8.3.
Time allocated to food production by Embu adults from 7:00 am to 9:00 pm (March 1985 to February 1986).

	Minutes/Day				
Food Production	Average Man	Average Woman	Average Household Men	Average Household Women	Total Hhld
Subsist Agricult	80	121	106	167	273
Non-Agriculture	53	22	70	30	100
Total	133	143	177	197	374

Baksh, Trostle, Neumann, 1989

Of the 273 minutes per day spent at subsistence agriculture by the average household's adults, at least 211 minutes (77%) were devoted to maize and beans (Table 8.4). This figure should perhaps be slightly higher since some of the time allocated to "unspecified plots" may well have been time spent in maize and/or bean plots.

The task of separating the 211 minutes spent devoted to maize and beans among these two crops is complicated since some of this time cannot easily be attributed to one or the other. In an effort to estimate the total amount of time devoted to maize and the total amount of time devoted to beans, the time in the "mixed" category is divided according to the proportions of "known" time that adults devote to maize and beans. It is estimated that the average man devoted 35 minutes to maize and 25 minutes to beans, and the average woman devoted 39 minutes to maize and 56 minutes to beans (Table 8.5).

TABLE 8.4.
Time allocated to subsistence agriculture by Embu adults from 7:00 am to 9:00 pm (March 1985 to February 1986).

	Minutes/Day				
Subsistence Ag. Plot Type	Average Man	Average Woman	Average Household Men	Average Household Women	Total Hhld
Maize	22	33	29	46	75
Beans	16	47	21	65	86
Maize and/or Beans	22	15	29	21	50
(Subtotal)	(60)	(95)	(79)	(132)	(211)
All Other Crops	10	18	13	25	38
Unspecified	10	8	13	11	24
Total	80	121	105	168	273

Baksh, Trostle, Neumann; 1989

TABLE 8.5.
Time allocated to subsistence agriculture by Embu adults from 7:00 am to 9:00 pm (March 1985 to February 1986).

	Minutes/Day				
Crop	Average Man	Average Woman	Average Household Men	Average Household Women	Total Hhld
Maize	35	39	47	54	101
Beans	25	56	33	77	110

Baksh, Trostle, Neumann; 1989

Perhaps the most important figures in Table 8.5 are the calculations for all household adults combined. Thus, a total of 101 minutes per day were spent producing maize, and 110 minutes per day were spent producing beans. These time inputs were then compared with crop yields to evaluate the efficiency of production of these two main crops, both in terms of actual weight and kilocalories (see Table 8.6). These yields per time reflect the ability of current subsistence agriculture techniques to supply adequate food, both through direct production and food purchased with money from the sale of crops. They also help explain why the emphasis is put on certain crops. For instance, an analysis of the maize and bean yields per unit of time offers more insight to the high area emphasis on maize cultivation. Indeed, while maize is cultivated on 51% more land than beans, maize cultivation produces 53% more grams per minute of work than bean cultivation. Perhaps more significantly, a minute of work produces 68% more kilocalories from maize than from beans: a total of 94 calories are produced from a minute of work devoted to maize vs. 56 calories from a minute devoted to beans (see Table 8.6). One implication of these findings is that although "beans/maize" plots are nearly as productive as "maize only" plots in terms of kilocalories produced per square meter, the cultivation of "beans/maize" plots is considerably more labor demanding.

TABLE 8.6
Grams and calories of maize and beans produced per minute of labor by the average household

Crop	Total
Maize	
Household minutes per day	101 (= 36865 per year)
Kilos produced per year	952
Grams/minute	26
Calories/minute	92
Beans	
Household minutes per day	110 (= 40150 per year)
Kilos produced per year	682
Grams/minute	17
Calories/minute	56

Baksh, Trostle, Neumann; 1989

From a standpoint of labor efficiency, it appears that Embu farmers are utilizing their maize-bean land properly. If anything, the question is not why do households cultivate more land with maize than beans, but rather, why is more bean area (and, as a consequence, more bean time) not converted to maize?

We suggest that, aside from the important cultural preference for both foods, the cultivation of beans in significant amounts adds more security to the subsistence production system than would be afforded if only maize was emphasized. Although maize is more productive per square meter and per minute of labor, its yields vary considerably from season to season and zone to zone. Maize therefore appears to be more susceptible to climatic fluctuations or extremes than beans, which are more reliable and less risky to produce. Also, beans bring a higher price on the market than maize (the average price of beans in local markets was eleven Kenyan shillings per kilo from May 1984 through January 1985, compared to four shillings for maize), and this no doubt influences the planting behaviors of some farmers. In addition, beans, as a nitrogen-fixing legume, are likely enhancing soil nitrogen and thereby contributing to maize production. And finally, from a nutritional standpoint, bean production is important since, by consuming maize and beans simultaneously, all essential amino acid (protein) requirements are fulfilled. However, while this latter point is of extreme adaptive importance, the factors of labor efficiency, area efficiency, food preferences, risk management, and economic considerations clearly are major influences on planting behavior.

It is of interest to discuss briefly the division of subsistence crop labor by sex. As is apparent in all the time allocation tables presented thus far, the average woman spent significantly more time (121 minutes per day) than the average man (80 minutes per day) producing subsistence crops.

At the household level, women provided about 62% of subsistence agriculture work time (see Table 8.3). Women's contribution to the production of beans was particularly high, well over twice that of the men's. Women's contribution to maize production was about 15% higher than men's.

Another perspective on the division of labor is provided in Table 8.7, which presents the time spent by the average man and woman at specific subsistence agricultural tasks. The only major task that men spent significantly more time at than women was garden digging (i.e., soil preparation). In contrast, women spent significantly more time at the major tasks of planting, weeding, harvesting, threshing/winnowing, and husking/shelling. The extreme importance of women's contribution to household food production is obvious.

TABLE 8.7.
Division of labor by sex, for subsistence agricultural activities, for Embu adults (18 years and above) of the 42-household agriculture study sample, from 7:00 am to 9:00 pm (March 1985 to February 1986).

Subsistence Agricultural Activity	Minutes/Day Average Man	Minutes/Day Average Woman
Clearing	4	2
Terracing	1	<1
Burning	<1	0
Digging	20	10
Plowing	1	0
Planting	10	14
Fertilizing	3	2
Mulching, Watering	2	<1
Weeding	13	27
Spraying/Dusting, Other Pest Control	3	3
Harvesting	8	25
Threshing, Winnowing	2	11
Husking, Shelling, Drying, Storing	7	21
Unspecified	6	6
Total	80	121

Baksh, Trostle, Neumann; 1989

Time Allocated to Cash Crops

As indicated in Table 8.8, the average Embu man spent 70 minutes per day engaged in the production of cash crops, and the average woman, 19 minutes per day. Because there are 1.33 men and 1.38 women in the average household, the total time spent by the average household at cash crop production was 119 minutes per day.

As would be expected, the bulk of cash crop labor time was spent producing coffee (Table 8.9). Indeed, about 92% of all household cash crop time (110 of 119 daily minutes) was devoted to coffee. Comparatively little time was devoted to cotton and tobacco, about four and five adult minutes per household per day, respectively.

The division of labor by sex in cash crop production is, in a sense, the opposite of that for subsistence crop production. Whereas women (at the household level) performed 62% of all subsistence agricultural labor, men performed 79% of all cash crop labor. The combined subsistence and cash crop time was remarkably similar for both: 199 minutes per day for men, and 193 minutes per day for women.

As illustrated in Table 8.10, the average man spent more time at each cash crop agricultural activity than the average woman. As women's contribution to subsistence agriculture is invaluable to the household economy, so too is men's contribution to cash crop production. Patterns such as these must be considered by government administrators and development agencies concerned with improving or otherwise introducing changes to the agricultural system.

TABLE 8.8.
Time allocated to cash labor by Embu adults, from 7:00 am to 9:00 pm (March 1985 to February 1986).

	Minutes/Day				
	Average	Average	Average Household		Total
Cash Labor	Man	Woman	Men	Women	Hhld
Cash Crops	70	19	93	26	119
Other Cash Labor	143	32	190	44	234
Total	213	51	283	70	353

Baksh, Trostle, Neumann; 1989

TABLE 8.9.
Time allocated to cash crops by Embu adults, from 7:00 am to 9:00 pm (March 1985 to February 1986).

Cash Crop Agricult. Plot Type	Minutes/Day Average Man	Average Woman	Average Household Men	Household Women	Total Hhld
Coffee	65	17	87	23	110
Cotton	1	2	1	3	4
Tobacco	4	<1	5	<1	5
Total	70	19	93	26	119

Baksh, Trostle, Neumann; 1989

TABLE 8.10.
Division of labor by sex for Embu adults, for cash crop agricultural activities, from 7:00 am to 9:00 pm (March 1985 to February 1986).

Cash Crop Agricultural Activity	Minutes/Day Average Man	Average Woman
Terracing	1	0
Digging	5	<1
Planting	2	<1
Fertilizing	1	0
Watering	<1	0
Weeding	7	2
Spraying, Other Pest Control	2	<1
Pruning (Coffee only)	12	1
Harvesting	16	10
Curing (Tobacco only)	1	0
Batching (Tobacco only)	2	<1
Winnowing (Coffee only)	<1	0
Drying	<1	<1
Transporting to sell; collecting payout	8	2
Obligatory Coop Work & Office Visits	13	3
Other	<1	1
Total	70	19

Baksh, Trostle, Neumann; 1989

Summary of Findings

Analyses of the data initially involved generating simple descriptions of how categories of individuals spent their time. For example, the Kenya time allocation data demonstrate that a number of important differences exist between how lead males and lead females spend their time (see Table 8.2). Although some of the differences are largely expected, such as the fact that females spend considerably more time at food production and care of self and others (including child care), and men spend more time at cash labor activities; other differences are perhaps more enlightening, such as the observation that males devote considerably more time to inactive, recreational, and social activities. More insightful patterns emerge from analyses of specific time allocation categories and comparisons of time use to nutritional status and other study findings.

For instance, it was demonstrated that the production of maize and beans and the generation of a cash income are critical for the well-being of Embu households. It is apparent that most farmers are generally cultivating maize and beans in proportions that 1) maximize labor and land resources, 2) are culturally satisfying, 3) produce some critical income, and 4) minimize ecological risks that would be associated with a dependency upon only one crop. In other words, the agricultural planting behavior of Embu farmers is largely rational.

Yet, given that many Embu are moderately malnourished even during periods of relative environmental and economic stability, something in their productive and/or economic systems is problematic. One basic problem is that Embu households consume the equivalent of only about two-thirds of the maize and bean kilocalories they produce. Actually, because households purchase about 27% of their food, and some of this includes maize and bean supplies that are required before new harvests are available, households sell probably close to half of their original production, but then are forced to buy some back later at higher prices.

We believe that Embu well-being could be improved with three basic production and economic changes. First, some relief could be obtained by increasing total maize and bean production through the increased productivity of land already under cultivation (we do not advocate that more land be planted with these or other crops in cases where it is available, as this would shorten fallow periods and likely encourage soil degradation). Specifically, improved literacy, greater use of on-farm manure as fertilizer, and annual visits by agricultural extension offices have been shown to increase crop yields. For households with relatively little land, the potential to improve yields lies perhaps entirely in gaining access to and implementing new and improved agricultural techniques.

A second change that would benefit farmers would be for them to keep more of their produce for household consumption. The nutritional benefits of this are obvious. Of equal importance, households would benefit economically in the long run since they would not be required to spend proportionately more cash to buy back important supplies of maize and beans in the weeks preceding new harvests. Improved storage facilities would be required, but these would bring the additional benefit of decreased losses to pests and spoilage.

A third, essential change is the development of alternative sources of cash generation. This change is, in fact, necessary before households can begin keeping significantly more of their own produce. In addition, there is substantial evidence that income contributes to maize and bean production, in part through the hiring of labor and the purchase of fertilizer. However, we cannot state what the alternative income generating activities should be as another major finding is that the production of cash crops, including coffee, does not contribute to increased food consumption during periods of "normal" environmental and economic stability. Households that are heavily involved in cash crop production enjoy higher incomes and socioeconomic status, but do not eat any better than those who produce small amounts of cash crops. Indeed, the nutritional status of men in households highly involved in cash crops is low (regardless of SES level), probably because they tend to work harder. On the other hand, women of high SES households have high nutritional status, possibly because these households have a large number of productive adults and because they can afford to hire others to perform labor demanding subsistence agricultural activities that these women would otherwise perform. See the chapter on the Impact of Drought and the Embu Agriculture report (3) for a more complete discussion of cash crops and nutrition.

THE INFLUENCE OF REPRODUCTIVE STATUS ON WOMEN'S TIME USE (2)

To determine the effects that pregnancy and infant care have on Embu women's economic productive work activities, time use patterns were calculated for women at different stages of pregnancy and lactation, as well as for women who were neither pregnant nor lactating. Detailed reproductive data were collected monthly, and household socioeconomic status (SES) data, quarterly.

Activity specific time allocation of Embu women by reproductive status, as a percent of total daily time (7 am to 6 pm) is shown in Table 8.11. A comparison of the number of hours devoted to activities by non-pregnant, non-lactating and pregnant/lactating women over a two year period are presented in Table 8.12.

Analysis of Embu women's time use by reproductive status reveals that the demands of pregnancy require women to decrease the amount of time spent on subsistence agriculture, commercial activities, housework, and tending animals, and to devote more time to breast feeding and child care. Agricultural and economic activities are curtailed especially in the third trimester of pregnancy and the 1st period of lactation. Over the two-year period that a cycle of pregnancy and lactation requires, pregnant/lactating women are able to allocate less time to commercial and subsistence agriculture, and other work activities than the women who are neither pregnant nor lactating (NPNL). This adds up to approximately 53 fewer eleven hour work days. Rest during pregnancy and child care responsibilities during lactation are the major factors accounting for these changes in time use patterns. A very salient problem is that women in the third trimester of pregnancy consume on the average 1350-1450 kcal/d, about a third less than required at this stage of pregnancy.

The loss of 53 eleven hour work days over two years by a pregnant/lactating woman can place considerable stress on Embu household food production and income generation. Because the reduction in time for women of "low" and "medium-low" SES households is greater than for women of "high" and "medium-high" SES during the third trimester of pregnancy, the impact of pregnancy appears to present an even greater hardship for those households already in poor economic condition.

This data provides insight into how pregnancy and lactation require women to adjust their time use to meet the demands of both reproductive and farm labor activities. This information reinforces the fact that regardless of reproductive stage, women continue to work long hours. Nonetheless, during the third trimester of pregnancy and the first period of lactation, women must reduce their labor contributions to the household. Over time, this decrease in time spent in subsistence agriculture, commercial activities, and household work increases the risk of household economic insecurity. If energy intake were improved in pregnancy and lactation some of a woman's activities might increase, such as care of the house and compound.

TABLE 8.11.
Time allocation of Embu women by reproductive status, in percent of total daily time (7 am to 6 pm).

	Pregnancy Trimester		Lactation Period		NPNL
Activity	1st	3rd	1st*	3rd†	
Child Care	2.5	3.9	23.8	19.2	5.0
Work					
Animal Care	3.2	2.9	1.8	3.5	4.1
Commercial	13.3	8.3	5.7	10.1	13.2
Food Prep.	10.1	11.2	12.9	13.2	13.1
Housework	17.7	10.4	12.4	13.0	14.2
Manufacture	1.9	4.4	3.4	1.8	2.4
Subsis. Agric.	20.9	18.5	15.2	18.0	20.3
Wild Foods	0.0	0.2	0.0	0.3	0.0
Sub Total	67.1	55.9	51.4	59.9	3
Non-Work					
Ceremony, etc.	2.5	0.2	1.0	1.0	1.9
Eating	1.9	5.2	5.2	3.7	4.8
Education	0.6	0.4	0.0	0.3	0.4
Inactive	5.7	17.9	8.9	5.3	7.2
Grooming	2.5	3.1	1.8	2.3	2.6
Idle (Illness)	1.9	5.6	3.1	0.4	1.9
Recreation	0.0	0.0	0.1	0.4	0.4
Socializing	15.2	8.1	4.7	7.8	8.6
Sub Total	30.	24.8	21.2	27.8	
Total	99.9	100.3	99.9	100.2	100.1

Baksh, Neumann, Paolisso, Trostle, Jansen; (unpublished observations)
* 0-45 day post partum
† 3.6 months post partum

TABLE 8.12.
Comparison of the number of hours devoted to activities by NPNL women and pregnant/lactating women over a two-year period.

Activity Category	NPNL (24 Months)	Pregnant (9 mos) and Lactating (15 mos)	Difference
	Hours per Two-Year Period		
Child Care	403	1,020	+617
Work			
Animal Care	329	248	-81
Commercial	1,062	814	-248
Food preparation	1,049	1,008	-41
Housework	1,136	1,048	-88
Manufacture	194	204	+10
Subsistence Agriculture	1,630	1,495	-135
Wild Foods	0	4	+4
Non-Work			
Ceremony	152	105	-47
Eating	384	343	-41
Education	29	26	-3
Inactive	577	646	+69
Grooming	210	179	-31
Idle due to illness	155	155	0
Recreation	32	23	-9
Socializing	688	713	+25
Total	8,030	8,031	

Baksh, Neumann, Paolisso, Trostle, Jansen (unpublished observations)

Summary

Embu women, like women throughout the developing world, work extremely hard. On a year round basis, taking into account pregnancy, illness, and other factors, the average Embu women spends about 61% of her daily time between the hours of 7:00 am and 6:00 pm engaged in subsistence agriculture, housework, food preparation, commercial, and other work activities. The same woman spends another 11% of her time caring for children. An Embu woman's contributions to her household's subsistence and economic welfare is of paramount importance.

The information on women's time use by reproductive status is particularly relevant with regard to agricultural development in rural Africa and the roles that women play in this sector. While it has been established for some time that women contribute significantly to food production throughout sub-Saharan Africa, policy makers and development practitioners have been unclear as to the degree to which this contribution varies due to women's reproductive responsibilities. Such information is critical to the design and implementation of gender-sensitive agriculture development programs.

It is well accepted that agricultural development in Africa must address the needs and capabilities of the small farm. Increasingly, international donors and governments are recognizing that women farmers must become better integrated into agricultural development if the goals of increasing productivity and sustainability are to be achieved.

It is critical that agricultural development programs ensure that their activities do not increase household labor demands to levels that exceed those that will be possible for women to meet. Excessive direct demands on women's labor, or indirect demands due to changes in labor patterns of other household members, may force women to work beyond what is physically good for them and their infants. This could force women to decrease the amount of time spent in agricultural program activities to the extent that it could put those programs at serious risk for failure.

The information presented in this paper lends support to arguments that agricultural development programs that affect women farmers (which is almost all in sub-Saharan Africa) must include a broad-based understanding of the central role that the woman plays in the support and care of the family. In this context, closer links between agricultural development programs and family planning efforts could result in a reduction of overall work burden for women and allow them greater flexibility in responding to their own and their family's economic and health needs. Along with family planning efforts, the growing recognition by agricultural development practitioners of the importance of providing women with labor saving technologies should help women secure greater control over their time use. This will enable rural farm families to respond better to farming crises as well as opportunity. Most importantly, women need to increase their low energy intakes in pregnancy and lactation, not only to improve their reproductive outcomes and to support lactation, but to be able to carry on their usual activities.

In summary, an extensive and reliable data set is available on how the individuals of project households spent their time for an entire year. The examples provided above demonstrate that a wealth of data is available for the Kenya study population which can be used to address and understand a host of nutritional, health, agricultural, social, and other research topics.

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CHAPTER NINE.
IMPACT OF DROUGHT

Although subject to drought about every 10-12 years, Embu district includes high potential agricultural land that is not usually subject to serious drought or severe food shortages. A failure of the short rains in 1983, and the long rains in 1984 however resulted in poor harvests of maize, beans and millet in the upper zone and almost complete crop failure in the lower zones. The drought induced food shortage peaked from September through December 1984. Data on food intake, food sources (including market availability), food prices, nutritional status, and health status were collected before, during and after the food shortage. These data provided the opportunity to study household response and coping strategies, and the impact of transient nutritional deprivation.

METHODS

As described previously, during each month of the study, quantitative food intake measures were made two days per month and anthropometric measurements were carried out monthly (1). Daily rainfall data were obtained from the Embu Agricultural Research Station for the first six months of the study and the CRSP staff measured rainfall daily (to the nearest 0.1 mm) at four locations in the study area for the remainder of the study.

In order to detect fluctuations in household food intake, a monthly household kilocalorie intake ratio (HCIR) was calculated for each study household. A daily HCIR was obtained by dividing the total household kilocalorie intake by the total basal metabolic rate (BMR). Total BMR was calculated as the sum of the individual BMRs of the household members determined from age, sex and weight data and assumptions about activity levels using FAO/WHO/UNU equations. The monthly HCIR was then arrived at by calculating the mean of the daily HCIRs (1).

Household agricultural production data were collected monthly for major food crops. The amounts of the crops that were harvested, stored, sold, purchased and/or planted every month were determined through interviews with household heads. In addition, surveys of food availability and prices were made periodically in the five local markets. For each market visit, amounts and prices of all available foods were estimated and recorded.

Study households were surveyed to determine changes in food production, distribution, consumption and sources of food supply that occurred as a consequence of the drought-induced food shortage. Recall information was collected on foods eaten, the average number of meals consumed per day, whether wage labor was performed or new businesses started, and whether land, animals, or other possessions were sold in order to buy food.

Morbidity of household members was monitored weekly by structured questionnaires and/or observation and drought and non-drought periods compared. As discussed in the chapter and social experiences. For school-age children, classroom behavior was observed, as were social interactions on the playground. Cognitive skills were assessed, and school attendance was monitored during the period of food shortage and compared to non-shortage periods.

Thus, a broad range of effects of the drought could be studied in relation to physical and nutritional status, household economic activity, social interactions and behaviors, and caretaking and morbidity.

RESULTS

Comparison of rainfall totals by season for 1984 and 1985 with data from 1951 to 1980 indicate that the long rains of 1984 were very low. The long rains of 1984 were only 52% of normal, and 46% of this rain fell over four consecutive days in April. As a result, the long rain harvest of 1984 was a complete failure (see Figure 9.1).

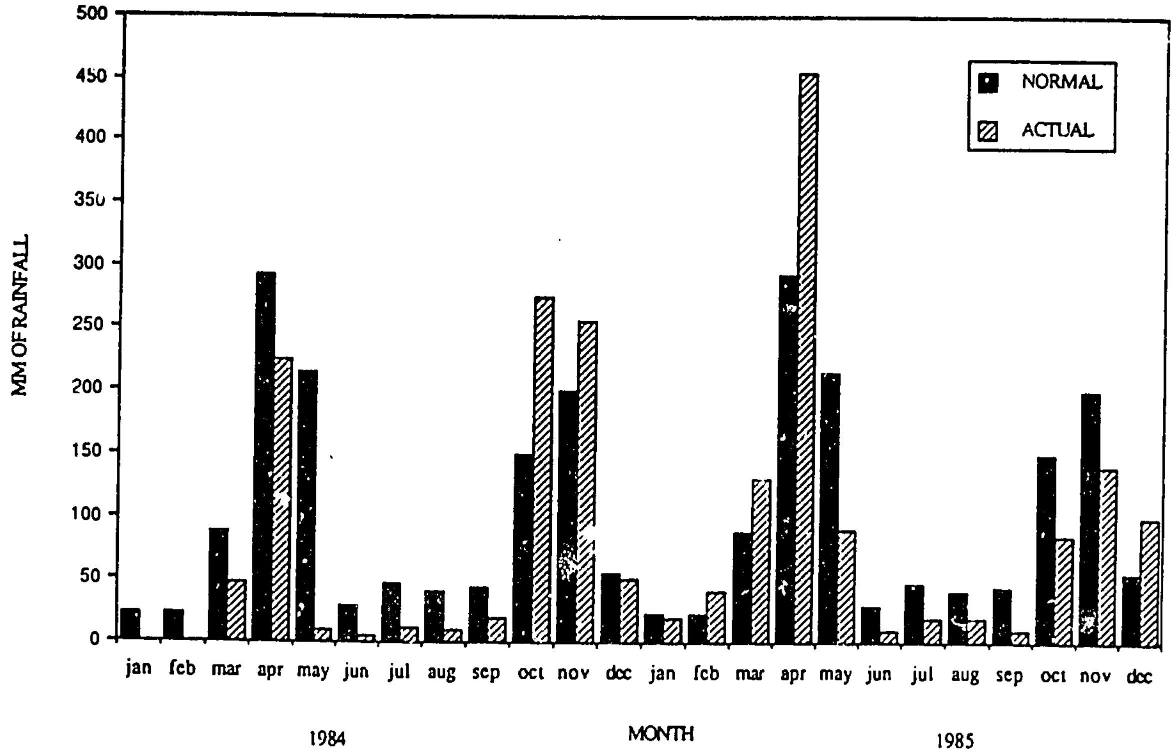

FIG 9.1 Comparison of normal and actual monthly rainfall amounts in the study area

Food Intake

A decline in total household food intake was observed from April through September 1984 (2). The lowest HCIRs were observed in August, September, and October of 1984, when the ratios were below 1.0 in 30% of households, as compared to 14% for the same months in 1985 (Figure 9.2).

Daily kilocalorie intake during the four periods by target individual is presented in Table 9.1. Lead males, lead females and schoolers all were observed to have statistically significant declines in energy intake during the food shortage, when compared to the period before the shortage. Pregnant, non-pregnant non- lactating and lactating women also experienced statistically significant declines in energy intakes during the four year periods (Table 9.2) as did lead males as shown in Table 9.1. Men showed a decline of about 22% and the lead females overall a 25% decline in energy intake. Pregnant women showed an even more severe reduction in energy intake, with a drop of about 28%. Women who were in their third trimester during the food shortage period had the greatest reduction in intake, which is cause for concern since this is a critical period of growth for the fetus. Lactating mothers also experienced severe declines in energy intake during the food shortage period, when increased energy intake is required for lactation.

School-age children experienced sharp declines of about 23% from their pre-shortage intake. Toddlers appeared to be somewhat "protected" from the impact of the food shortage, with small declines in intake observed. However, with growing children intake should steadily increase, whereas during the peak drought period, toddler intakes were several hundred kcals/day below recommended levels (see Figure 9.3). Infant supplementation was also examined. When infants were stratified by age, no statistically significant differences in intake from supplementation in drought and non drought months were observed.

A monthly intake of specific nutrients was compared to identify changes in diet quality. Consumption of protein, fat, carbohydrates, and iron followed the same pattern as kilocalorie consumption; intakes were the lowest in September 1984. A survey of study households revealed that 63% ate fewer meals during the drought than before, and 70% of all households reported eating less food per meal during the drought.

FIG: 9.2: Mean daily household kilocalorie intake ratio (HCIR) by month, 1984-1986

Neumann, Trostle, Baksh, Ngare, Bwibo; 1989

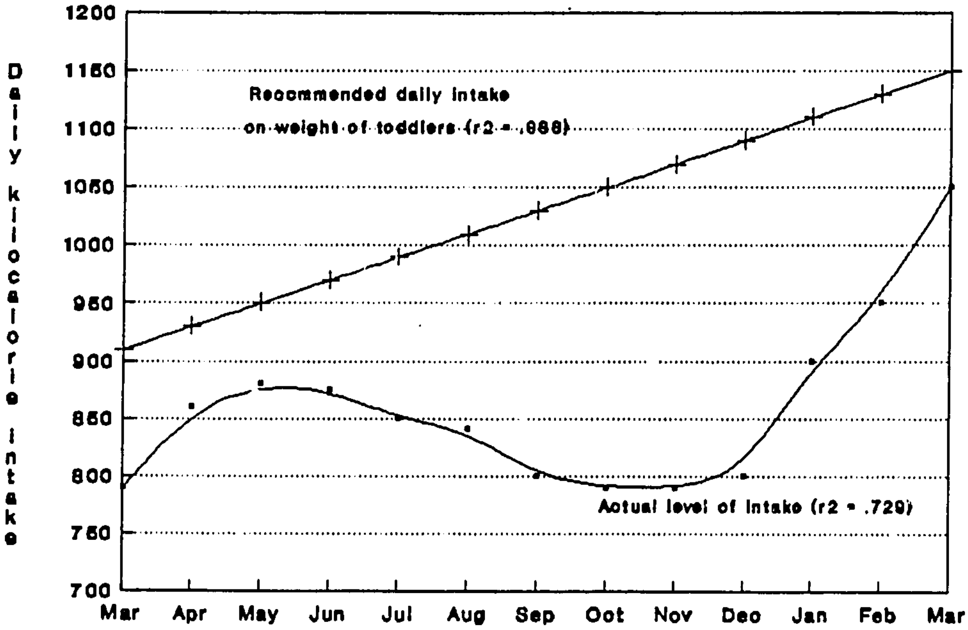

FIG. 9.3: Comparison of mean daily toddler kilocalorie intake by month (lines are polynomial regression lines)

TABLE 9.1a Daily kilocalorie intake during four periods by target individual

	n	Pre-Shortage Mean	± SD	Shortage Mean	± SD	Post-Shortage I Mean	± SD	Post Shortage II Mean	± SD
Lead males	112	2077	595	1621	479	2026	575	2069	553
Lead females	121	1727	451	1298	458	1725	462	1801	455
Schoolers*	117	78.2	19.3	60.2	17.0	75.8	24.1	na	na
Male	62	81.2	18.6	62.3	17.1	78.8	21.6	na	na
Females	55	74.7	19.6	57.8	16.7	72.4	26.5	na	na
Toddlers*	91	82.1	30.1	78.4	24.0	82.4	26.6	na	na
Male	41	78.7	28.9	81.0	24.5	81.4	25.5	na	na
Female	50	84.9	31.0	76.4	23.7	83.2	27.7	na	na

* Schooler and toddler intake is expressed as kilocalories per kilogram of body weight
Pre-shortage = Mar., Apr. and May of 1984
Shortage = Sep., Oct. and Nov. of 1984
Post-shortage 1 = Jan., Feb. and Mar. of 1985
Post-shortage II = Sep., Oct. and Nov. of 1985

TABLE 9.1b Statistical significance of differences between time periods using paired tests

	n	Pre-shortage to Shortage: % Pre-shortage intake lost to Shortage	p	Shortage to Post-shortage I: % Post-shortage I intake increase over Shortage	p	Shortage to Post-shortage II: % Post-shortage II intake increase over Shortage	p
Lead males	112	22.0	*	20.0	*	21.6	.0001
Lead females	121	24.8	*	24.7	*	27.9	.0001
Schoolers	117	23.0	*	20.6	.0001	na	na
Male	62	23.3	*	20.9	.0001	na	na
Female	55	22.6	*	20.2	.0001	na	na
Toddlers	91	4.5	NS	4.9	NS	na	na
Male	41	2.9	NS	0.5	NS	na	na
Female	50	10.0	NS	8.3	NS	na	na

* p = .001 - .009
NS = p > .10
na = insufficient data for a statistical comparison

TABLE 9.2a Daily kilocalorie intake for pregnant, non-pregnant non-lactating (NPNL), and lactating women during four periods

	Pre-shortage			Shortage			Post-shortage 1			Post-shortage II		
	n	Mean ± SD		n	Mean ± SD		n	Mean ± SD		n	Mean ± SD	
NPNL	129	1976	515	131	1457	499	128	1860	559	116	1863	489
Pregnant	109	1617	531	78	1172	395	52	1537	570	na	na	na
Trimester 1	45	1675	602	18	1166	509	21	1629	609	na	na	na
Trimester 2	56	1540	588	31	1242	419	21	1449	551	na	na	na
Trimester 3	44	1524	626	53	1154	411	28	1565	653	na	na	na
Lactating	28	1986	727	85	1391	467	82	1892	529	28	1944	776

na = insufficient data for a statistical comparison
Pre-shortage=Mar., Apr. and May of 1984
Shortage=Sep., Oct. and Nov of 1984
Post-shortage I=Jan., Feb. and Mar. of 1985
Post-shortage II=Sep., Oct. and Nov. of 1985

TABLE 9.2b Statistical Significance of differences between time periods using paired t-tests

	Pre-shortage to shortage		Shortage to Post-shortage I		Shortage to Post-shortage II	
	% Pre-shortage intake lost to shortage	p	% Post-shortage I intake increase over Shortage	p	% Post-shortage II intake increase over Shortage	p
NPNL	25.8	.0001	21.8	.0001	22.0	.0001
Pregnant	27.5	.0001	23.7	.0001	na	na
Lactating	30.0	.0004	26.5	.0001	28.4	.0011

Nutritional Status

Weight loss of household members occurred almost simultaneously with the onset of the food shortage, thus making weighing a useful early warning tool. Weight losses recorded are based on cross-sectional analyses and may differ from longitudinal analyses reported in the chapter on Resting Energy Expenditure. Adults lost considerable amounts of weight during the drought; a mean loss of 3.4 kg in men and 3.5 kg in women (see Figure 9.4). The mean monthly weight of toddlers and school-age children as a percentage of median weight for age for January 1984 through May 1985 is shown in Figure 9.5. Nearly two-thirds (65%) of school-age children did not gain any weight, and 14% lost weight from August to December 1984. Mean percentage of median weight for age values showed a dramatic decline in September through November, when the food shortage was at its most severe. Stunting among school children also increased as growth declined. Toddlers' weight gain was interrupted (see Figure 9.5) and height increased very little in response to the small declines in intake noted previously. The most striking observation was the increase from 2% to 6% in the prevalence of severe protein/energy malnutrition among children, including clinical cases of kwashiorkor with edema and wasting, necessitating the opening of a temporary nutrition rehabilitation unit.

Consumption of Local Food Crops

Embu farmers attempt to store enough maize and beans after each harvest to provide for adequate intake until the next harvest (3). The usual consumption pattern of white maize corresponds to the timing of the harvests. Consumption is usually the highest during January-March and June-August, and then lessens until the next harvest. Average daily household consumption of home grown white maize for July-August 1984 was 872 g compared with 2,152 g for the same period in 1985. Consumption of home grown kidney beans for July and August 1984 was 358 g compared with 1,075 g for the same period in 1985. Over 90% of the households reported eating foods during the drought that they normally did not eat. The most common alternative items were yellow maize (94%), sukumawiki (Brassica oleracea), (79%), cassava (55%), green pawpaws (55%), kiambuu bananas (52%), wheat flour (46%), sweet potatoes (40%), and arrowroot (Colocasia antiquorum) leaves (40%). In addition, insects and grubs, which are occasionally eaten, were being eaten more frequently.

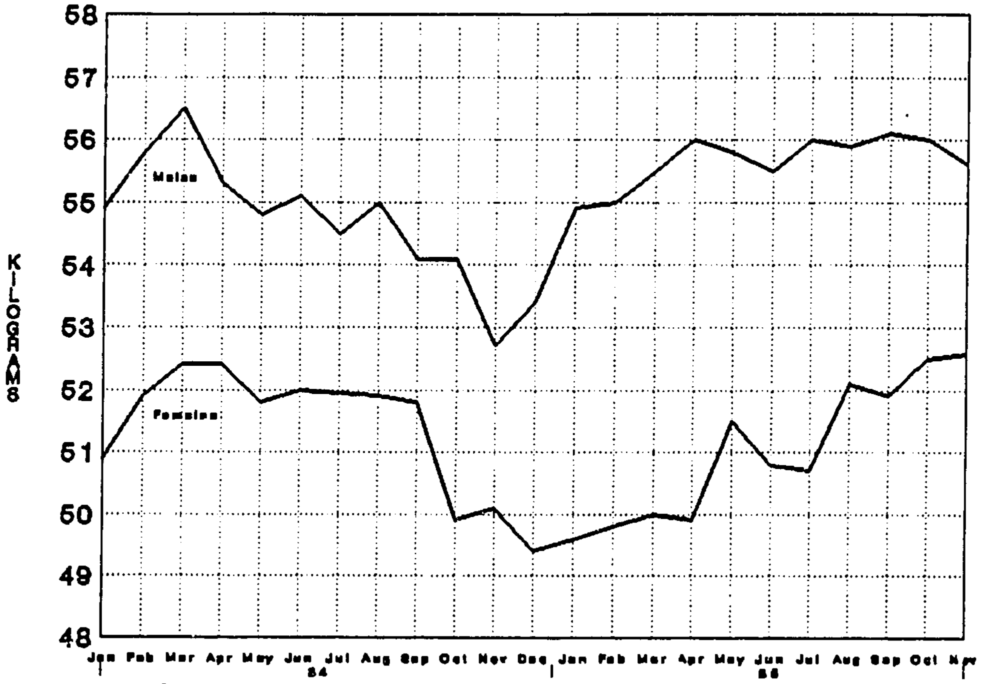

FIG. 9.4: Mean monthly weight of male and non-pregnant, non-lactating female heads of households, Jan 84-Nov 85

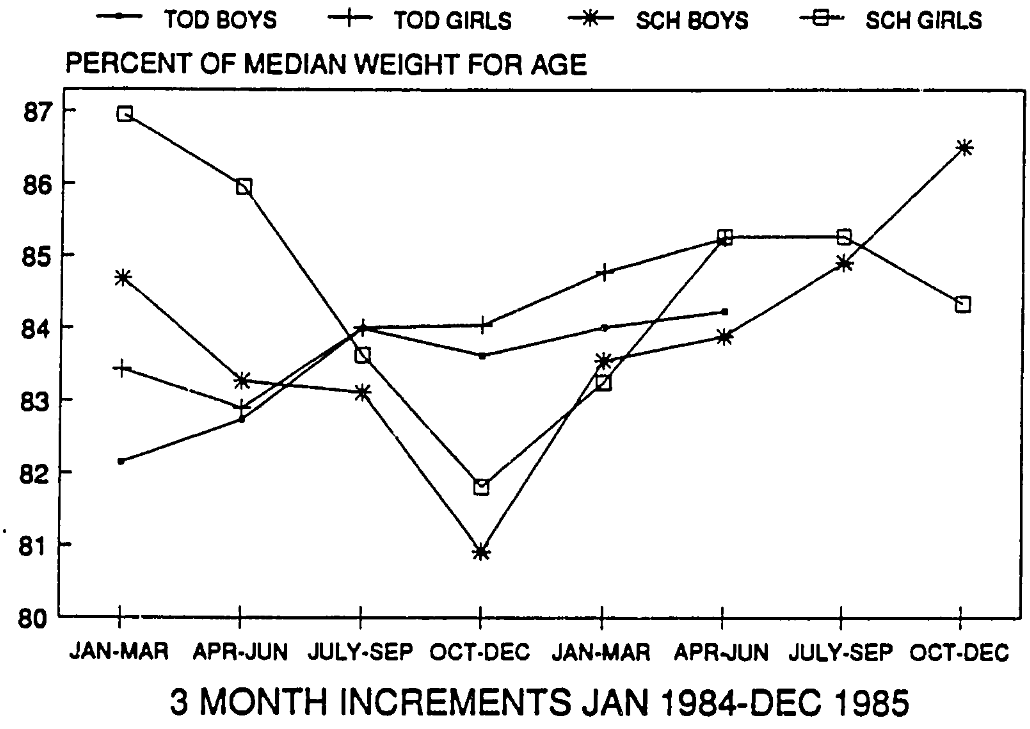

FIG 9.5 Mean monthly weight of toddlers and schoolers as a percentage of median weight for age Jan 1984 - Dec 1985

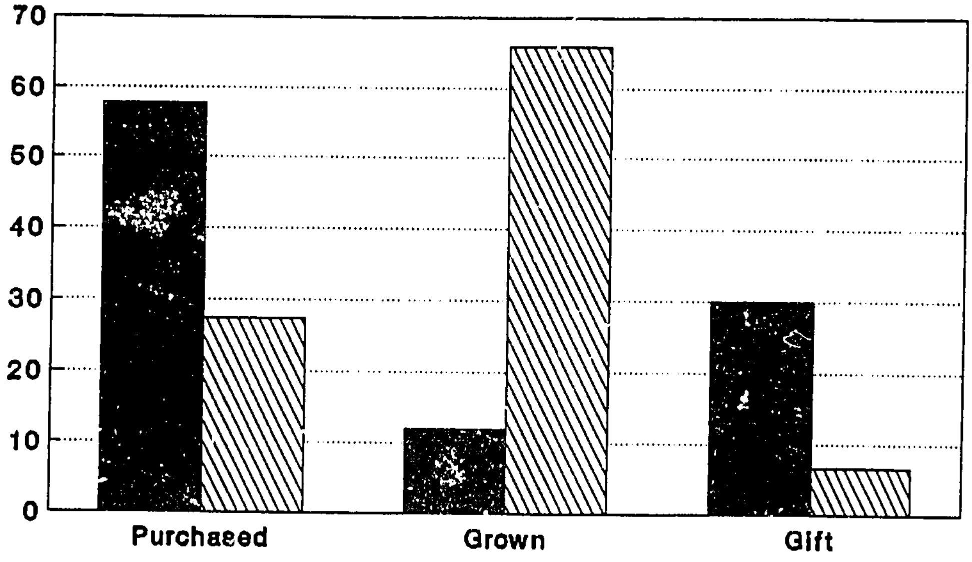

FIG. 9.6: Average household consumption of 12 selected food items, Sept. Oct. and Nov. of 1984 and 1985

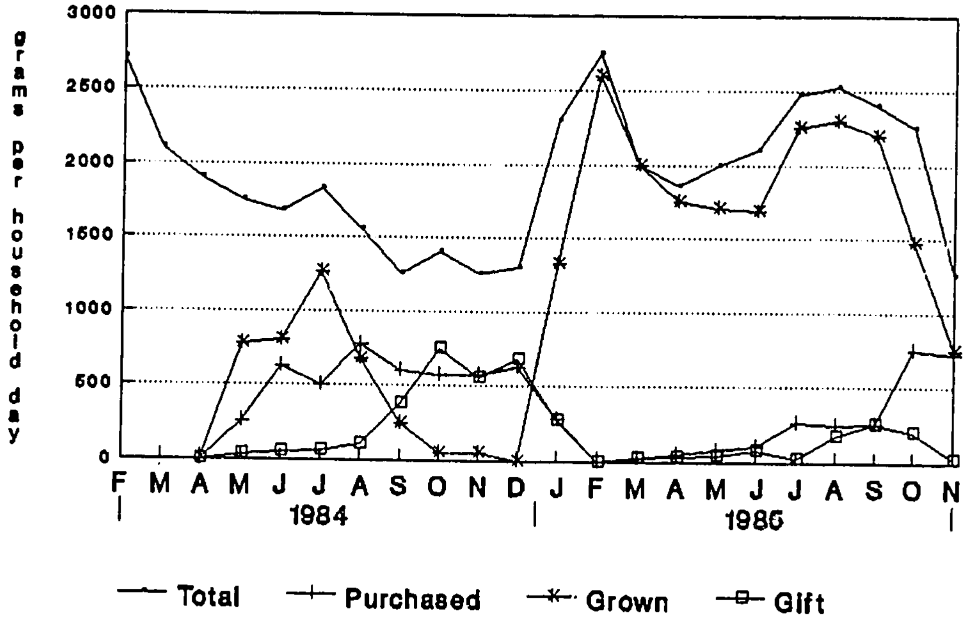

FIG. 9.7: Average daily household consumption of maize by source (white and yellow combined)

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Changes in Food Sources

The sources of the twelve foods that constitute the bulk of household intake were examined as shown in Figure 9.6. In 1984, 58% of this "food basket" was purchased, compared to only 27% in 1985. In 1984 households grew only 12% of the kilocalories in the food basket, as compared to nearly 66% in 1985. Virtually all households reported that the male and/or female household head resorted to some means of generating income that they normally would not have pursued.

Another major source of food during the drought was donations. Distinct from receiving CRSP initiated food aid, study households also received aid from friends and relatives (41%), the government (24%) and local churches (15%).

Household energy intake increased somewhat in December 1984 and January 1985 despite the fact that crops were not harvested until late February 1985. This was due in part to the CRSP food assistance program.

Many families purchased foods during the drought. Therefore local food prices and availability became critical. The prices of selected items in local markets reached their highest levels in November 1984, as households became increasingly dependent on purchased foods. Foods brought in from non-drought areas were abundant in the local markets. so availability was not a problem as it was in July, August and September. However, households had to commit substantially more of their financial resources to maintain the same level of intake, and for some households prices put food out of their reach. As people sold livestock to generate cash for basic foodstuffs, meat, specifically goats, flooded the market, and meat prices were relatively low.

Maize Consumption

During the drought, all forms of maize accounted for 76% of the total kilocalories consumed by the households. This figure dropped to 71% during the post-drought period although the total quantity of maize consumed per household increased (see Figure 9.7). Purchased and donated maize were the primary energy sources during the drought, accounting for 72% of all kilocalories consumed by the household. During the post-drought period, maize grown by the household was the major source of calories (44%) with purchased maize as a less important source (19%). As shown above, overall household kilocalorie intake levels fell by 21% on average from their pre-drought levels.

Impact of Small-Scale Coffee Production on Household Energy Intake

The impact of cash crop income derived from the production of coffee on household nutrition during the drought was examined (4). The drought appeared to have little effect on the cash crop harvest. No statistically significant differences in coffee income were observed between 1984 and 1985. Bivariate correlations were examined between coffee income and household energy intake before, during, and after the drought.

There were no correlations observed between the level of coffee income and household energy intake (HCIR) during the period of normal production. Thus food intake does not appear to be directly influenced by the household's involvement in coffee production.

In the post-drought period, income was positively related to the contribution made by home grown maize to total intake. However, coffee income did not correlate with the amount of maize purchased. Coffee income may enable farmers to purchase more production inputs, such as fertilizer, and therefore produce more maize to satisfy family needs. During normal seasons, production is often equal to or in excess of need, and thus farmers rarely need to purchase more maize or to apply the profits from coffee production to improve maize output.

During the drought, coffee income correlated positively with the contribution of purchased maize to the household diet. Thus, during the food shortage, income was used to purchase the maize needed to support the level of energy intake. While income derived from coffee production correlated positively with the amount of maize purchased by the household, there was no significant correlation between the amount of maize purchased and HCIR. This contradiction is clarified when household size is considered (see Figure 9.8).

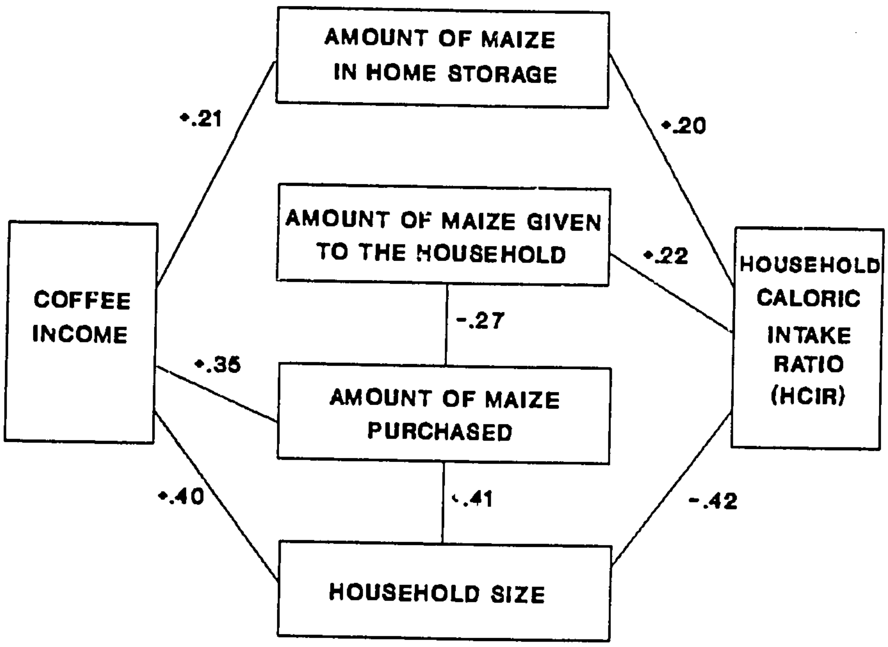

FIG 9.8: Significant bivariate correlations between characteristics during the drought (all correlations significant at $p < .01$, N=155)

Multivariate analysis was conducted to examine determinants of HCIR during the drought (see Table 9.3). Household size, the amount of maize purchased during the drought, the amount of maize given to households in the form of aid were found to account for 46% of the variation in HCIR. Coffee income did not demonstrate a statistically significant effect on HCIR when placed in the equation. When the same variables were used to explain household energy intake in the post drought period, only household size and the amount of maize grown on the farm produced statistically significant effects. Together those two factors explain 17% of the variation in HCIR.

Households were categorized by size, and level of coffee income to examine their nutritional performance during the drought. Regardless of the level of cash crop income, small households performed better than large ones during both drought and post-drought periods. Households with the highest cash crop incomes purchased more maize during the drought, but they also had significantly more mouths to feed. Their larger sizes canceled out the advantages of being able to purchase more food and they were left with smaller intakes than those households with lower incomes and fewer individuals to support.

In summary, despite the reliance on purchased foods during the drought, no direct relationship was found between the level of cash crop income and the level of household food intake during this period. This was found to be due primarily to the intervening factor of household size. When size is held constant, coffee income does not produce any statistically significant differences in HCIR during nor after the drought.

TABLE 9.3 Multiple regression analysis of the factors influencing the household caloric intake ratio (HCIR) during the drought (N=154)

Variable	Parameter estimate	Standard error	p	Standardized estimate
Intercept	1.4507	.0687	.0001	0
Household size	-.0915	.0092	.0001	-.6640
Maize purchased	.0002	.00003	.0001	.4933
Maize in home storage	.0003	.00008	.0001	.2349
Maize received as gift	.0002	.00003	.0001	.4187

Mean HCIR = 1.228
F = 33.604
Prob > F = .0001
Adjusted R-square = .4585

Behavioral and Cognitive Effects

One study focused on the effects of the food shortage on behavioral changes in a group of toddlers and their caregivers and on a group of school-age children (5). Behavioral patterns are compared across the three periods (before, during, and after the food shortage).

As mentioned in the section on food intake, during the food shortage period the toddlers seemed somewhat protected relative to the caregivers and school-age children in that their energy intake did not decline. While it is probable that the toddlers' food intake increased less than might normally be expected during the drought, food intake did not dip. The toddlers did not show behavioral changes as a result of the drought.

For schoolers and women, however, there were downward trends in food intake. Mean decrease in energy intake during the food shortage period was 200 kcal/day for schoolers and 400 kcal/day for women.

It was observed that the frequency of holding and basic care behaviors by the caretakers, mainly mothers, fell off sharply from before to during the food shortage period, possibly because the mother had less energy to devote to carrying her toddler. At other times such declines were more gradual, reflecting maturation of the child. Thus, it seems that the food shortage precipitated an abnormal decrease in these behaviors.

To explore this issue further, matched pairs of toddlers were used to examine caregiving behaviors. Paired t-tests revealed that during the food shortage, as opposed to before or after that period, mothers cared for and held their toddlers less, $t=-2.89$, $p<.01$ ($n=26$) and $t=-2.03$, $p<.05$ ($n=26$), respectively. There was also less caregiver talk directed at the child, $t=-3.29$, $p<.01$ ($n=26$). Thus, during the food shortage, maternal behavior directed toward the child was affected, although toddler behaviors remained unchanged.

These behavioral changes might have consequences for subsequent developmental skills. Decreased holding may actually be of benefit to the child as it might allow for more active exploration. On the other hand, during the food shortage, mothers also spoke to their toddlers less. It was established earlier that Embu toddlers have more advanced language skills if their mothers direct more verbalizations toward them (6,7). Thus, the drought might have had a negative impact on toddlers' language skills and corresponding cognitive development, particularly if the drought had lasted longer.

In contrast to the toddlers, the energy intake of the caregivers and the school-age children decreased and their behaviors changed during the food shortage. One explanation for these findings is that during the period of food shortage, energy intake was insufficient to sustain normal activities. Mothers had less energy to devote to child care and stimulation. School-age children had less energy to sustain activity levels on the playground and concentration levels in school. School attendance also declined.

The behaviors of the school-age children affected by the food shortage were activity level and off-task behavior in the classroom. A certain amount of activity is necessary for active exploration and learning. If this active exploration and learning is reduced over a period of time, cognitive development may be impaired. In support of this notion, high activity level, as measured over the school year, in this sample, was associated with better cognitive outcomes. The correlation between high activity level and a cognitive score (based on a combined score from the Verbal Meaning and Raven's tests) was $r=.29$, $p<.05$ ($n=109$), while the correlation between low activity and the cognitive composite score was $r=-.35$, $p<.05$ ($n=109$). In addition, off-task behavior in the classroom was associated with poorer cognitive skills (8). Thus, a decrease in food intake has immediate effects on behaviors important for learning and thereby possible long-term consequences for cognitive development.

DISCUSSION

The Embu drought primarily affected one growing season and harvest, the long rains in 1984. Household and community food reserves were very scarce and were unable to sustain the normal level of energy intake. The Nutrition CRSP Program sponsored a relief program which supplied a limited amount of foodstuffs to all the households in the study area. Little food assistance was available from other agencies.

Despite the food relief efforts, energy intakes were severely affected. Of particular concern, pregnant and lactating women experienced drastic declines in energy intake. In order to promote optimal pregnancy outcomes, pregnant women should consume approximately 200-300 additional kilocalories per day, while an additional 500 kilocalories per day are required by lactating mothers (9). Therefore given that Embu women actually experienced decreases of approximately 300 kcals/day during the food shortage, the cost of the drought may be measured in an increase in the number of low birthweight babies, higher infant morbidity and mortality, and an increased need for medical services.

School-age children were also adversely affected by the food shortage. Schoolers experienced reductions in intake, growth levelled off, and increases in school absenteeism were reported due to diversion of cash normally spent on school fees and to physical weakness. Playground activity levels and behavior were also affected (see Chapter 6).

These negative outcomes make it clear that to avoid such degradations, measures must be taken to reduce household vulnerability to acute food shortage. A strengthened capacity to adopt positive responses in times of shortage needs to be emphasized. Possibilities include:

1) Household and community food storage facilities.

2) Shifts in agricultural practices to increase the number and quantity of drought resistant crops and varieties grown (e.g., millet and sorghum), as well as the willingness and ability of farmers to switch to "famine crops" (e.g. cassava) during a period of food shortages.

3) Household and community seedbanks.

4) A simple but valid information gathering system which can monitor community markets, household food supply and availability, crop yields, rainfall, and nutritional status in order to act as an "early warning system" for potential food problems.

5) Water schemes to protect the farmers against complete reliance on rainfall for their crops.

6) The central government moving food produced in one area to areas where food is in short supply.

7) Increased income generation, cash availability or credit schemes to allow farmers to purchase food and seed during emergencies.

8) Price control over main staples when they reach the market, to make them affordable.

These last three suggestions are particularly important, as although it is commonly assumed that there is little market food available to purchase during food crises, it was found, on the contrary, that the availability of major foods was greatest in November 1984. Ironically, this was well into the period of lowest food intake and highest prices. It seems to indicate that it was not a lack of food that produced the sharp decline in intake, but rather how accessible that food was to the average household.

However, an increase in cash crop production may not be the solution to increasing accessibility, as the relationship between income and food is not as straight-forward as the data may indicate. There are important considerations that need to be made in a determination of whether income will replace lost production. The first one is the way in which income is retained by the household. For example, coffee payouts are made three times a year. They correspond with the beginning of the school terms and often have automatic deductions for school fees. Savings accounts are rare in this area and since they can actually involve negative interest rates, the incentive is for families to spend their income shortly after receiving it. Therefore, even if a household has a great deal of income from coffee, that income may not be held as cash. Indications are that most income is either spent on agriculture inputs (fertilizer, seeds, labor, etc.), on obligations such as school fees or loan repayment, or on capital assets such as livestock and household possessions.

Another consideration in the relationship between income and food consumption is the issue of "an acceptable level of energy intake." On average, the HCIR remained above the level of 1.0 during the drought. This means that households were consuming enough food to meet their basal metabolic needs. The question of how high that level should have been is an important consideration in the decision to purchase maize. If those in the household responsible for the allocation of resources perceived a 20% drop in intake to be acceptable, then they may have chosen not to utilize the full force of their purchasing power on more

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food. The concept of an "acceptable level of energy intake" is a subjective one. Since wide-scale starvation did not occur, it may have been that families were content to endure this drop in intake. Since there was no way of knowing exactly how long the drought would last, retention of some purchasing reserve would seem to have been a most prudent course of action. Also the various food relief efforts were acting to alleviate the need to purchase more food. The roles of purchased maize and coffee income may have been significantly more important had food from other sources not been available.

Finally, although foods were highly available on market day at a given site, this may have been not because there was a surplus in the storehouse but rather because few could afford the steep prices. Had prices been at normal levels, foods might have been considerably less available. Perhaps prices were high because some could afford them (or had to give in to them), and this retarded the volume of exchange, leaving an apparent but somewhat deceptive impression of plenty.

To the extent that this hypothesis is correct, government policies need to consider the impact of unfavorable terms of exchange. Specifically, opportunistic price increases during crises, particularly by long-distance merchants who profit from localized shortages, need to be prevented. Close government supervision of inter-regional food distribution, with nominal, controlled price increases, would presumable go far towards minimizing problems such as were seen in Embu.

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CHAPTER TEN.
SUMMARY OF FINDINGS AND POLICY AND PROGRAMMATIC IMPLICATIONS

SUMMARY

Highlights of the most salient research findings are presented here. The findings presented are the ones that governmental and non-governmental agencies in Kenya felt were most important for policy formulation and program planning in Kenya.

The Diet

1. *Mild-moderate malnutrition is associated with adverse functional consequences in all age groups.* However, the effects on infants, children and pregnant and lactating women are the most far reaching. This form of malnutrition is the most prevalent and cannot be ignored or dismissed as harmless. Chronically low intake of food deficient in energy and micronutrients, is expressed as stunting, under-weight for age and decreased fat stores.

2. *The quantity (energy) as well as the quality (micronutrients) of the diet in rural Embu is generally poor.* Limited food availability is a reflection of poverty; large family size and land pressure; and a vulnerable food supply due to a precarious rain-dependent agricultural system with periodic drought.

3. *The quality of the Embu diet* is generally poor, reflecting a low fat intake and very low intake of animal source protein (poultry, meat, fish) with resulting deficiencies of vitamin B_{12}, iron and zinc. Moreover, the bioavailability of zinc and iron are low because of the high phytate and fiber content of the diet and high tea consumption. In addition, other B-vitamins, particularly riboflavin, and calcium and iodine intake are notably low. However, total protein is adequate in amount and quality.

4. *Anemia is wide spread*, with over 50% of the toddlers and pregnant women affected. Schoolers and men are affected to a lesser degree. The anemia is predominantly due to iron deficiency aggravated by hookworm. However, B_{12} deficiency and possibly folate deficiency in pregnancy are associated with the macrocytic anemia seen in women and children. Endemic malaria also contributes to the anemia problem.

5. *Non-use of iodized salt* by the majority of the households in this iodine deficient area, adversely affects growth, cognitive function and reproductive outcomes of study subjects. High cost was stated as the main barrier to the use of iodized salt.

6. *A high infectious disease burden* in children negatively affects their food intake and growth and cognitive development.

Functional Outcomes of Food Deprivation

Four specific functional areas were found to be negatively affected by deficient food intake. These are reproductive outcome, growth, cognitive function and behavior and morbidity.

Reproductive Outcomes

7. *Pregnancy food intake and gestational weight gain are extremely low.* Women in Embu progressively lower their energy intake by 25% to 30% of their pre-pregnancy intake by the third trimester. Their pregnancy weight gain is about 50% of that recommended for European or American women. They gain an average of 6.3 kg, with 8% of the women experiencing no weight gain and even weight loss. Despite this, infants are born with a mean birth weight at or slightly below the reference values (40th percentile), but the mean birth length is considerably reduced to the 20th percentile. Low birth weight is seen in 10% of infants. Overall, 16% of infants are intrauterine growth retarded, indicative of maternal malnutrition.

Maternal size upon entry into pregnancy and maternal energy intake during pregnancy relate positively to birth weight and length. Also, maternal energy intake promotes pregnancy weight and fat gain.

8. *Mothers in late pregnancy lose body mass (fat and muscle) to support fetal growth.* To conserve energy they double their inactive time in the third trimester and in lactation. Resting energy expenditure (REE) does not decline in pregnancy to accommodate the decrease in energy intake, thereby making more energy available.

9. *Mothers enter lactation with little or no additional fat stores to support lactation.* Although energy intake increases to pre-pregnancy levels, it is not adequate to support lactation sufficient for normal growth of the infant beyond two or three months plus the mother's normal daily activities. The growth rates of infants markedly decline between three to six months, particularly for length. Thus, the infants appear to "absorb" the bulk of the energy deficit experienced by pregnant and lactating women. In response to the mother's perception of insufficient milk , early supplemental feeding of the infant is started at two to three months. Supplemental feeding may worsen the problem as a slight negative effect on infant growth and a slight increase in febrile illness are seen.

Growth

10. *Stunting is the leading expression of a diet chronically low in energy and micronutrients.* Inadequate linear growth starts in-utero. By three to four months of age linear growth further decelerates to a greater extent than weight, and by six months of age the infants are stunted. Once stunted, the children remain so due to diets that are inadequate in energy and important micronutrients necessary for growth (zinc, iron, iodine).

The children once stunted do however grow at low normal rates but never catch up to reference levels particularly for stature. The stunting persists throughout childhood, adolescence and into adulthood. This affects both sexes, although in girls, there is a small degree of catch-up in late adolescence. About 10% of adults are above median reference values, but the majority of the adults are under the median, as evidenced by a mean z-score for height of -1.5. Thus, most adults do not fulfill their genetic potential.

The main determinants of poor childhood growth appear to be low energy and micronutrient intake (zinc, iodine) and high illness prevalence. Parental height, an expression of a shared environment and genetic makeup also strongly predicts the child's height.

Serious functional consequences are found with stunting, particularly in the area of cognitive development and morbidity, even when controlling for low food intake and SES. Consequently, stunting cannot be viewed as a successful adaptation to chronic underfeeding.

Cognitive and Behavioral Outcomes

11. *Energy intake, diet quality and size, particularly height are important determinants of cognitive function and school performance.* Animal protein and fat (markers of diet quality) and iodized salt use are particularly important for cognitive function and learning. In toddlers, symbolic play, and in schoolers, activity level, are important pathways for learning and are linked to food intake. Even after controlling for home environment and parental attributes such as literacy and cognitive scores, food intake and the child's size predict cognitive function and school performance. Follow-up studies of toddlers showed that earlier intake of a high quality diet (animal source protein) and height affected cognitive function even three years later. For children to benefit from their environment and from education, they must be well-fed.

Morbidity

12. *Energy intake in children and in the adults are protective against serious illness.* For mild illness food intake is less important than environmental factors such as household sanitation and household illness exposure. The better fed the mother, the less the illness experienced by the child as she is better able to maintain the household with better sanitation and child care.

Short stature largely due to low food intake and poor diet quality was found to be a risk factor for acute lower respiratory infection in toddlers.

13. *Acute infectious illness in children significantly reduces their food intake.* Given the high illness prevalence and long duration of severe illness, a sizeable energy and growth deficit may occur over time causing further deceleration of growth. Despite increased

intake during convalescence (compensatory eating), the deficit is never completely made up.

Morbidity, per se was also found to decrease cognitive function in toddlers and schoolers, even after controlling other related factors including food intake, size and parental and household characteristics.

Adaptations to Low Energy Intake

14. *An important finding with widespread policy implications is that no "cost free" metabolic adaptations were found in response to decreased energy intake* either during a severe drought or during pregnancy. This refutes commonly held assumption that people can adapt successfully to low energy intake.

Studies of resting energy expenditure (REE), performed on men and on women during pregnancy, lactation and non-pregnancy with comparisons between drought and non-drought periods did not show a significant decline in resting energy expenditure beyond that associated with change in body weight. Nor were work tasks performed more efficiently (with less energy) than by better fed people. The main adaptations seen in men and women were a loss of body weight and fat and a decline in physical activity. These are hardly "cost-free" adjustments in terms of health, daily activities and productivity. Neither is stunting in children a "cost free" adaptation to decreased food intake.

Lessons Learned from a Severe Drought Associated Food Shortage

15. *Lessons were learned from a closely observed severe food shortage in the study area associated with drought.* The extreme vulnerability of rural subsistence agricultural households in regard to food security, particularly for those dependant wholly on rain-fed agriculture is striking.

The following observations were made: An over-dependence on maize, rather than diversification with use of more drought-resistant staples such as millet and sorghum; a lack of household stores of grains and seed; poverty which did not allow many households to purchase available, but expensive maize and beans in the markets. The flooding of the market with low priced goat meat and initial scarcity of maize and other staples.

In retrospect, useful early warning signals for impending food shortage, which could be monitored by governmental officials, were missed rainfall and shift in the basic diet to rarely eaten items. Most insightful were interviews of the farmers who were able to predict poor or no harvests early in the drought. Also, loss of body weight, particularly in school children and adults occurred relatively early in the drought.

In conclusion, mild-moderate malnutrition, a result of chronic energy deficit and poor diet quality, causes long-term functional impairments in the important domains of growth, cognitive development, reproduction, morbidity experience and physical activity. To ignore this problem not diminishes well-being and competence of individuals and households.

POLICY AND PROGRAMMATIC IMPLICATIONS

Suggested policy and programmatic implications of the Nutrition CRSP findings and some suggestions for possible interventions follow.

1. *Awareness of scope and consequences of mild-moderate malnutrition.* National leaders and senior decision makers must be made aware of the fact that chronically low food intake and mild-moderate malnutrition affect large segments of the population and that there are adverse long term consequences for all age groups. Particularly affected are growth, reproductive outcome, cognitive development, school performance, disease resistance, and productive activity. The problem affects far more people than severe malnutrition but would be much less costly to deal with on a per capita basis.

2. *Increase production and availability of food and improve diet quality.* To improve the quantity and quality of food, appropriate agencies in government, development organizations and communities themselves must be made aware of not only poor food availability but the limited nutrient value of the diet as well. Framers of agricultural policy and promoters of economic development need to promote both the production of more of the basic diet staples as well as the variety of foodstuffs necessary to supply adequate micronutrients to the diet.

Increased productivity must, in particular, be stimulated at the local level by means of programs helping the subsistence farmer. Increased extension outreach, particularly by women extension workers to work with the women who are the main subsistence farmers is especially important. Also needed are improved seed and use of less expensive and more organic fertilization methods. Households should increase the variety of staples from primary dependence on maize to include more drought resistant crops. Moreover, programs through extension are needed to improve household food storage using appropriate technology to combat aflatoxin and post-harvest losses due to insects, birds and rodents.

To improve diet quality, the agricultural sector needs to combine forces with departments of livestock, small animals and fisheries. (Even among the agricultural CRSP entities only recently have there been attempts at collaboration between the agriculture and the food-oriented human nutrition CRSPs. The aquaculture, topsoils, small ruminants, cowpeas, and peanut CRSPs would have much to offer, particularly in Africa). Nutrition education is needed to encourage people to include more animal source protein in their diets using locally available or potentially available foods.

On a community level, small animal production to improve animal source protein will have to be expanded. Non-governmental organizations (NGO's) have taken the initiative in helping to establish fish ponds, raising ruminants and rabbits for food and increased milk production for household use and income generation.

Education about traditional methods of food processing such as fermentation and germination of cereal grains and legumes must be increased. These methods increase the digestibility and bioavailability of micronutrients by decreasing the phytate and improve the energy density, especially valuable for weaning foods. This would also improve the B_{12} levels of the food.

Iodized Salt Use

All salt must be iodized. Diet quality would be greatly improved by government involvement in the production, subsidization, quality control and distribution of iodized salt. Legislation may be necessary to assure that all salt is iodized. Education as to why iodized salt should be used and the consequences of iodine deficiency is needed.

3. *Food Security Improvements.* Farmers must be encouraged to diversify and grow not only maize but more drought resistant crops such as millet and sorghum and devise strategies for growing short term "famine crops" such as cassava. Community and household storage of emergency grains and seed banks are needed so that people will not eat their seed as food in times of shortage.

A price control mechanism during food shortage times appears to be indicated for commodities that may flood the market from other parts of the country but at greatly inflated prices. Also, reasonable community stock piles of strategic foodstuffs should be available for sale at fair prices in times of food shortage. This will help stabilize prices and will enable people whose harvests have failed to purchase food at affordable prices. In times of food shortage, food-for-work programs or opportunities to earn income would be highly desirable.

4. *The need for income generation in the rural area is great.* The necessity of obtaining cash for such expenses as school fees and agricultural inputs (seed, fertilizer, implements) has forced farmers to sell food off as cash crops, saving very little to see them through to the next harvest or planting season. Households should be encouraged to keep more of their produce for household consumption which will benefit them in the long run. They then will not need to spend proportionately more cash to buy back maize and beans just prior to the harvest at prices higher than their sale price.

More small, local income generating activities need to be developed. For example, the highly successful small credit schemes or revolving loan funds for poor rural women that enable them to start small enterprises often involve food production and sales and have been highly successful in some parts of Kenya and in other countries . Examples are small bakeries, dairies, raising of chicken for eggs and food, small animals, and production of woven products. These improve diet quality, either directly or indirectly, by providing income for the women.

5. *For improved reproductive outcome,* it is extremely important to focus on the nutritional and health status of women long before they become pregnant in order to promote favorable birth weight and infant growth and to protect maternal nutritional status. Existing child health and pregnancy health care services and the school health programs need to be further strengthened. Interventions must start early in life, assuring that girls receive attention, feeding and care equal to that of boys. At the very least, school age girls must be targeted for nutritional education, supplementation, and treatment of anemia and parasites.

Because of low food intake and poor weight gain of pregnant women in Embu there close monitoring during pregnancy of weight gain and fat gain using arm circumference is indicated. Food supplements should be made available for malnourished women as well as treatment of anemia and malaria. Pregnant women and lactating women must not only maintain their pre-pregnancy food intake level, but increase their pregnancy intake, at least in the second half of pregnancy and during lactation. Massive education has to be directed to the mothers who progressively lower their food intake throughout pregnancy to avoid having a "difficult delivery". A corollary of this is to improve obstetrical facilities for difficult deliveries.

During lactation, nutrition education has to be directed to the mothers about the necessity of increasing their intakes even above pre-pregnancy level. Mothers, during lactation, should be monitored using weight and arm circumference along with the growth monitoring of their infants. This could be accomplished with a single scale by weighing the infant by mother/child difference.

6. *Stunting or small stature cannot be viewed as a harmless adaptation or as a genetic manifestation.* Government leaders and agencies and the people themselves must recognize the origin and consequences of stunting. Stunting reflects the level of economic development and has functional consequences of a serious nature in regard to learning, productivity, illness and reproductive outcome. Also, health and nutrition workers and parents have to realize that the condition is reversible if a quantitatively and qualitatively adequate diet is provided. The earlier in life an adequate diet is provided, the easier it is for catch-up growth to occur.

Simple methods for measuring linear growth can be devised and stature obtained possibly twice a year in infancy and in the toddler years. Otherwise, the nutritional stunting will be missed, particularly where weight is appropriate for the given height. With improved reporting, the ages of infants and toddlers are now generally more available than previously for evaluating length or height for age.

Mothers, to improve their milk production and hence the growth of their infants, should themselves be supplemented during lactation, with a diet of adequate energy and micronutrient content. Supplemental feeding of the infant should be delayed until 4-6 months, with weaning foods based on milk products and animal proteins in addition to cereals and legumes. It is important to ensure high quality protein and calcium intake. Appropriate technology such as fermentation is useful in increasing caloric density and decreasing phytates in young child feeding.

In terms of iron adequacy, citrus fruit should be encouraged at each meal to enhance iron absorption. An important adjunct is the elimination and prevention of hookworm.

Stunting can be reversed in the infants and toddlers and some degree of catch-up growth in schoolers and even in adolescents if enough food of sufficiently high quality were supplied. For example, for a toddler to show catch-up growth, he/she would need to increase energy intake by at least 15% over a long term period.

In light of their high energy expenditures and activity, the schoolers need to improve their energy intake. Children should be educated to bring food to school to eliminate the unnecessary round trip home in mid-day. Schools can serve as an excellent site for nutrition education, school gardens and small animal projects. Height and weight can be measured periodically at school. School children can also disseminate information to their families. On site school feeding can improve energy and micronutrient intake, Addition of iodized salt and iron would be of particular benefit. Governments are not getting a good return on their investment in primary education unless children are in a position to learn and benefit from being in school. Education is a vital link to economic and agricultural development.

7. *Any nutrition improvement must be considered simultaneously with infection.* Both health workers and parents should be made aware of the connection between infection and feeding. Health workers must emphasize to parents the importance of feeding children recovering from severe prolonged illness and encourage the child to eat as much as possible for as long as possible, to compensate for the illness-associated loss of intake.

8. *Lessons learned from the drought.* Important lessons learned with respect to food security primarily relate to early warning and monitoring systems to alert the government about the probable need for food relief. As school children and adults were found to have lost the most weight, school-based weight monitoring and arm circumference (MUAC) measurements can serve as an early warning system of a disturbance in the food situation. As mentioned, mothers could be weighed or MUAC obtained during growth monitoring sessions for their children.

Market surveys for prices and availability of certain key food items should be initiated by local government officials and/or health or nutrition workers after the expected rains are missed. Systematic surveys of local farmers by extension workers early in a drought would be most informative about impending crop failures.

9. *Another food deprived member of the family may be the adult male.* Their body mass index is low, as are their fat stores. This may interfere with their activity and productivity. Men are classically bypassed in maternal child health programs and seek care only when ill. Nutrition education should be targeted at men as well as women and children with periodic weighing and/or circumference measurements and intervention if indicated.

10. *Women's Time Use studies* have shown that women work harder and longer than do men and have little time for recreation or free time. The implications for development and health and nutrition initiatives clearly are not for adding more tasks to the woman's already busy and long day *unless* there are labor saving technologies and more assistance for the women.

11. *Family Planning* services are badly needed in terms of accessibility and availability. It is clear from the CRSP data that the number of children in a household correlates negatively to food intake of the children and of the mother and growth and illness of the children. Also, the high reproductive burden of the continual cycle of pregnancy and lactation cuts deeply into women's economic and household activities. With improved nutrition for the mother and longer birth intervals, this situation might be partially alleviated. Family planning services must be made more available to the rural population.

In summary, an integrated multisectoral approach is required on the part of government and nongovernmental groups and community-based efforts to improve quantity and quality of the diet of rural families. People do not successively adapt to low food intake. Instead, their well-being and overall function are jeopardized thus impeding economic and agricultural development and greater self sufficiency.

APPENDIX A: PARTICIPANTS

THE NUTRITION CRSP KENYA PROJECT: 1983-1987.

Principal Investigators		Date
University of California, Los Angeles (UCLA)	Charlotte G Neumann, MD, MPH	1982-1987
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	Nimrod O Bwibo, MBChB, MPH	1984-1987
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	Doris H Calloway, PhD	1982-1987

The Nutrition CRSP Kenya Project Faculty Co-investigators.

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Consultants	Dr. Alfred Neumann (1983)	UCLA
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	Michael Baksh	1985-1986
Administrator	William Martin	1982-1986
Senior Field Staff	Dorothy Cattle, PhD	Anthropology
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	Michael Paolisso, PhD	Energy Expenditure, Anthropology
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	M. Marquardt MD	Morbidity
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Agriculture, time allocation	Michael Baksh, PhD
Education	Michael Espinosa, PhD
Child development	Mary Ann McDonald, PhD
Follow-up studies, cognition, growth	Susan D. Souza, MA
Statistics/Programming - UCLA	Murray Trostle, DrPh 1987-1991
	Linda Ferguson PhD 1991-1992

Collaborators - University of California, Berkeley

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Ford Foundation	Follow-up 1988	Cognition, growth
World Bank	Support of Data Analyses	
Dean Jamison, PhD		School Performance
Alan Berg, MA		School Performance
J. McGuire, PhD		Nutritional Deficiency
Richard Feachem		Morbidity (Adult)
WHO	Dr. Benbouzid	Breastfeeding, and child spacing
USAID/Kenya Agriculture	A. Smith J. Gingerich	Embu agriculture
Mothercare/USAID	Dr. M.A. Anderson	Maternal anthropometry and
	Ms. Coleen Conroy	Risk outcome detection for Pregnancy

UCLA	BRSG Grant, follow-up study in Embu African Studies Center UCLA	travel grants x2 to hold workshops in Kenya on CRSP findings
UNICEF	David Alnwick	Hosted two review meetings in Kenya
UCLA	Dean AA Afifi, PhD Alfred K. Neumann, MD, MPH Derrick B. Jelliffe, MBBS	
University of Nairobi, Applied Nutrition program	AA Kielmann, MD, DrPh	Hosted data analysis workshop
USAID/Kenya Mission	Health officer	General guidance

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Many of the senior and junior staff have gone to other positions and were not part of the data analyses or write-up efforts of the past three years but their contributions are fully appreciated. Special recognitions go to the field directors Dr. Eric Carter, Dr. Michael Baksh; other senior field staff Dr. Dorothy Cattle, Dr. AA Jansen, Michael Paolisso, Mark Marquardt, Erastus Njeru and Duncan Njeru.

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Neumann CG, Beaton G, Carter E, Paolisso M, Gardner G, Bwibo NO. Effect of reduced food intake on resting metabolic rate in rural Kenyan men. The 14th International Congress of Nutrition, Seoul, Korea, August 20-25, 1989.

Neumann CG, Sigman M, Bwibo NO. Cognitive development and school performance in mild - moderately malnourished school-aged children. International Congress of Pediatrics, Paris, France, July 20-25, 1989.

Neumann CG, Bwibo NO, Sigman M. Cognitive function of Kenyan school children in relation to nutrition, schooling and home environment. International Society of Tropical Pediatrics and African Pediatric Society. Nairobi, Kenya, March 1990.

Bwibo NO, Neumann CG, Jansen AAJ. Infant feeding and child spacing in rural Kenya. International Society of Tropical Pediatrics and African Pediatric Society. Nairobi, Kenya, March 1990.

Neumann CG, Weinberg S, Murphy S, Marquardt M, Carter E, Bwibo NO. Impact of acute morbidity on food intake in rural Kenyan toddlers. International Society of Tropical Pediatrics and African Pediatric Society. Nairobi, Kenya. FASEB, March 1990.

Neumann C, Paolisso M, Carter E, Jansen AAJ. Resting metabolic rate in undernourished pregnant Kenyan women. FASEB, AIN. Washington D.C., April 1990.

Neumann CG, Kirksey A, Pelto G, et al. Infant feeding and child spacing: A three country study (based on Nutrition CRSP Data). International Society of Breast Milk and Lactation, Asilomar, November 15, 1990.

McDonald MA, Espinosa M, Neumann CG. Playground Behaviors of mild-to-moderately malnourished Kenyan children. Society of Research in Child Development, Seattle, Washington, April 18-20, 1991.

Baksh M, Neumann CG, Paolisso M, Trostle RM. The influence of reproductive status on rural Kenyan women's time use. NCIH, Crystal City, VA. International Health Conference, June 23-26, 1991.

Trostle RM. The impact of drought on food consumption patterns in central Kenya. UCLA International Conference on the Impact of Natural Disasters. Los Angeles, California. July 10, 1991.

Neumann CG, Jansen AAJ, Carter E, Bwibo NO. Onset and determinants of stunting in young rural Kenyan children. VIth International Congress of Auxology. Madrid. September 15, 1991.

Ballard T, Neumann CG, Marquardt M. Malnutrition and lower respiratory infections in Kenyan children. New Orleans, APHA 1991.

Neumann CG, Marquardt M, Haggerty J, Espinosa M, Bwibo NO. Marginal iodine deficiency in rural Kenyans: Thyroid hormone status and functional outcomes. FASEB. Anaheim, CA., April, 1992.

Neumann CG, Oace S, Murphy S, Bwibo NO, Calloway C. Low B-12 content in breast milk of rural Kenyan women on predominantly maize diets. Stockholm, Sweden. August 1992.

INVITED PRESENTATIONS

Jansen AA, Neumann CG, Carter E, Weinberg S, Bwibo NO. Pregnancy Outcome and Subsequent Infant Growth in Women with Marginal Malnutrition. UCLA School of Medicine, Department of Pediatrics, Grand Rounds, 1989.

Morbidity and Cognitive Development in Marginally Malnourished Kenyan Children. UCLA School of Medicine, Department of Pediatrics, Grand Rounds, 1989.

Functional Outcomes of Chronic Energy Deficiency in Rural Kenyans. UCLA African Studies Center, 1990.

Functional Effects of Marginal (Mild-Moderate) Malnutrition in School-Aged Children. State of California, Child Health Disability Program Update on Nutrition. Palm Springs, California, May 1990.

Neumann CG, Gardner G, Paolisso M, Carter E, Bwibo NO. Studies of resting energy expenditure (REE) in rural Kenyan adults: are there adaptive changes? Fifth Conference for Federally Supported Human Nutrition Research Units and Centers. Bethesda, Maryland, Feb. 20-21, 1991.

Energy Intake and Human Function. UCLA School of Public Health. Lectures two to three times a year in courses, doctoral seminars, etc.

REVIEW MEETINGS HELD IN KENYA

January 15-17, 1992

As a follow-up to an earlier review meeting held in Kenya, two meeting were organized between 1989 and 1992. Review meetings to disseminate findings and discuss policy and programmatic implications were held in Embu and Nairobi and hosted by UNICEF (Dr. David Alnwick). Dr. Suzanne Murphy also attended to present the findings concerning nutrient content of the food and visit the field site. Professor Bwibo and C. Neumann co-chaired the meeting. Representatives from agriculture, health, education and the Nutrition Planning Office of the Central Bureau of Statistics attended. Also present were University of Nairobi Collaborators and former project staff.

A second meeting on a smaller scale was convened in Embu to share CRSP findings with the district health, agriculture, nutrition, and welfare officers in Embu. Local chiefs, NGO representatives and community development officers attended. The community leaders presented some of the projects they initiated based on findings of the earlier CRSP and discussed new initiatives. These were extremely valuable meetings.

March 9-12, 1989

This meeting was primarily a data-analysis workshop for Kenyan co-investigators and collaborators and other interested parties from the Ministry of Health, Applied Nutrition Program, and Medical school and Central Bureau of Statistics who wished to use the Kenya Nutrition CRSP data for analyses. A mini course with hands on microcomputer laboratory experience using the CRSP data and manual was held at the Applied Nutrition Program, University of Nairobi hosted by Professor AA Kielmann and UNICEF.

Professor Ann Coulson, UCLA, and EK Njeru, MPH, the former CRSP data manager served as instructors. Dr. Bwibo and Dr. Neumann acted as consultants and resource people. Updated tapes and documentation have recently been sent.

APPENDIX C: DISSERTATIONS AND THESES USING KENYA NUTRITION CRSP DATA

DOCTORAL

Thomas JC. Risk factors for diarrhea among young Kenyan children for diarrhea. Ph.D. dissertation, 1987, University of California, Los Angeles.

Ngare DK. Simple predictors of low birth weight at the community level: Their potential application in primary health care for the prevention of adverse pregnancy outcomes in rural Kenya. Ph.D. dissertation, 1990, University of California, Los Angeles.

Trostle RM. Differential household survival during a drought induced food crisis in central Kenya. Ph.D. dissertation, 1990, University of California, Los Angeles.

Ballard T. Risk factors for lower respiratory disease in rural Kenyan children. D.PH dissertation, University of California, Los Angeles, June 1992.

Kiamba J. Determinants of growth in rural Kenyan infants. Ph.D. dissertation, Iowa State University. PhD 1991.

Espinosa M. Food intake, nutritional states and effect on behavior in schoolers. Ph.D. dissertation in progress, University of California, Los Angeles. June 1992.

MASTERS

Waswa J. Nutritional status of Kenyans in old-age. Nairobi, Kenya, 1989.

Kwa C. Nutrition, Immunity and Infection. University of California, Los Angeles, 1987.

Njeru EK. Predictors of anemia in rural Kenyans: A logistic regression analysis. University of California, Los Angeles, 1988.

Gustafson L. Prenatal factors related to birth weight in Kenyan women. University of California, Los Angeles, 1990.

Lapin R. Developing a Household Morbidity Measure for a Rural Kenyan Population, and Assessing Risk Factors for Morbidity. University of California, Los Angeles, 1992.

APPENDIX D: GRANTS OBTAINED FOR DATA ANALYSIS AND FOLLOW-UP

USAID - Study of Embu Agriculture, 1988-1989.

Ford Foundation (Nairobi)-"Post Famine Follow-up Study". 1988.

World Health Organization - "Breast Feeding and Child Spacing: A Three Country Collaborative Study" in collaboration with Purdue Univ. and Univ. of Connecticut. 1987-1989.

World Bank, Washington, DC Data Analyses Grants: (1988-1991).

> "Factors Effecting School Performance and School Participation of Kenyan Children."
>
> Cognitive Function and School Performance: Impact of Severe Drought and Food Shortage Upon Schoolers in Rural Kenya.
>
> Nutrient Deficiencies Among Rural Kenyans (Micronutrient).

Biomedical Research Support Grant (BRSG) - Data analysis.

MotherCare - Participation in Meta-Analysis of Maternal Anthropometry on Pregnancy Outcome. 1992.

Western Consortium - The Effect of Bioavailable Zinc and Iron on Growth and Cognitive Performance in Toddlers. 1992.