FOOD INTAKE AND HUMAN FUNCTION: A CROSS-PROJECT PERSPECTIVE

OF THE

COLLABORATIVE RESEARCH SUPPORT PROGRAM

IN

EGYPT, KENYA AND MEXICO

University of California
Berkeley
August, 1988

FOOD INTAKE AND HUMAN FUNCTION:

A CROSS-PROJECT PERSPECTIVE

of the

Collaborative Research Support Program

in Egypt, Kenya and Mexico

Doris Howes Calloway, Suzanne P. Murphy and George H. Beaton

Contributors

Lindsay Allen
Judith Balderston
Nimrod Bwibo
Adolfo Chavez
Osman Galal
Gail Harrison
Hugh Horan
Norge Jerome
Avanelle Kirksey
David Lein
George McCabe
Katherine A. Merrill
Charlotte Neumann
Gretel Pelto
Carl Rosberg
Steve Selvin

Contributing Institutions

Instituto Nacional de la Nutricion, Mexico
Nutrition Institute, Cairo
University of Arizona
University of California, Los Angeles
University of California, Berkeley
University of Connecticut
University of Kansas
University of Nairobi
Purdue University
University of Toronto

University of California, Berkeley
August, 1988

ERRATA TO FOOD INTAKE AND HUMAN FUNCTION: A CROSS-PROJECT PERSPECTIVE

(August 29, 1988)

Shortly after the copies of Food Intake and Human Function: A Cross-Project Perspective were mailed to you it was discovered that the numbers in several tables had been altered in the final editing process. Please make the following four corrections in all your copies of this report.

Table 4 (page 34): Iron Intake for Egypt Schoolers should be 12.9 ± 9.0 (not 9 ± 9.0).

Table 5 (page 38): Male Birth Weight for Egypt should be 3.32 ± .49 (not 3.32 ± 4.9).

Table 8 (page 49): Mean Duration of Upper Respiratory Illness Episodes for Egypt Schoolers should be 4.4 (not .4).

Table 15 (page 62): Energy Intake of Kenya women in trimester 2 should be 1463 ± 464 (not 463 ± 464).

We appologize for any inconvenience this may cause.

Department of Nutritional Sciences
119 Morgan Hall
University of California
Berkeley, CA 94720

ERRATA TO FOOD INTAKE AND HUMAN FUNCTION: A CROSS-PROJECT PERSPECTIVE

(September 19, 1988)

We extend our sincere apologies to Gail Harrison, whose name was inadvertently omitted from the contributors list on the title page of the report, Food Intake and Human Function: A Cross-Project Perspective. Please use the attached stick-on labels to add her name to the title page of all your copies of this report (a corrected title page is also included).

It has also been noted that body mass index is incorrectly defined on page 1 of Appendix C. Line 4 of the first paragraph should read "(weight divided by height squared)" (not "(height divided by weight squared)"). The labeling on the y-axis of the plots on pages 2 and 3 is correct (kg/m^2).

Thank you for your assistance in making these corrections.

FOOD INTAKE AND HUMAN FUNCTION:

A CROSS-PROJECT PERSPECTIVE

of the

Collaborative Research Support Program

in Egypt, Kenya and Mexico

Doris Howes Calloway, Suzanne P. Murphy and George H. Beaton

Contributors

Lindsay Allen
Judith Balderston
Nimrod Bwibo
Adolfo Chavez
Osman Galal
Hugh Horan
Norge Jerome
Avanelle Kirksey
David Lein
George McCabe
Katherine A. Merrill
Charlotte Neumann
Gretel Pelto
Carl Rosberg
Steve Selvin

Contributing Institutions

Instituto Nacional de la Nutricion, Mexico
Nutrition Institute, Cairo
University of Arizona
University of California, Los Angeles
University of California, Berkeley
University of Connecticut
University of Kansas
University of Nairobi
Purdue University
University of Toronto

University of California, Berkeley
August, 1988

ACKNOWLEDGEMENT

This report is a reflection of the dedication, hard work and sacrifice of the many, many field investigators and staff in Egypt, Kenya and Mexico and of the scientists, data managers and administrative staff of the collaborating institutions. These have been named and thanked in the individual reports of the three projects and the management entity, but we acknowledge here our collective appreciation of their critical contributions. Above all, this report is a tribute to the local community leaders and people of Kalama, Embu and Solis who recognized the importance of this research and allowed us to intrude upon their communities and homes for a period of years. Their generous cooperation went beyond our hopes and expectations. This was in all respects a participatory study which could not otherwise have been sustained.

We wish also to thank the Board on International Food and Agricultural Development and the United States Agency for International Development for making the research possible, and the External Evaluation Panel for their generous advice and guidance.

The Collaborative Research Support Program on Food Intake and Human Function was carried out under USAID grant no. DAN-1309-G-SS-1070-00. This monograph was prepared under USAID grant no. DAN-0262-G-SS-7079-00. The collaborating institutions contributed more than one-fourth of the total costs of the research.

PREFACE

I am honored, yet humbled, to write the preface to this monograph on the three-country study on food intake and human function. As a principal investigator of this important study, I had been intimately involved in the planning and implementation of this highly ambitious undertaking for seven years. From that vantage point, I was able to observe the master architect -- Martin J. Forman -- at work.

As director of the Office of Nutrition, Dr. Forman sought and obtained funds for the research reported here. Without his dedication, patience, perception, creativity and vision, the Nutrition Collaborative Research Support Program on Food Intake and Human Function would never have been done. Marty died on October 27, 1987, seven months before the Nutrition CRSP officially ended. We miss him.

As the new director of the Office of Nutrition, USAID, I have pledged to continue the work that Marty had started. The Nutrition CRSP data set must be analyzed completely and the results of the study shared widely and applied appropriately.

Martin J. Forman was an aovocate of data-driven nutrition planning and policy. That policy will continue. Nutrition programs within anc among countries will be shaped by the specific needs of the specific country or community.

The results of the Nutrition CRSP strongly reinforce the need to: determine and understand structure and composition in households; evaluate men's and women's current domestic and economic roles and preparation for these roles in changing social and economic systems; recognize cultural variability; identify societal uniqueness; emphasize ecologic diversity; and isolate commonalities among populations. Also, the Nutrition CRSP results underscore the need to reemphasize the nutritional impacts on such human functions as the ability to do physical and mental work, resist chronic and infectious diseases, and have healthy infants. All of these human functions influence individual and family well-being; they also intluence economic and social development - the central goals of USAID.

Norge Jerome
June, 1988

SUMMARY

The 1977 World Food and Nutrition Study of the US National Academy of Sciences gave its highest priority to determination of the functional consequences of chronic mild-to-moderate undernutrition. In 1981, the US Agency for International Development funded a Collaborative Research Support Program (CRSP) on this topic, under the auspices of the Board for International Food and Agricultural Development. Collaborating institutions were: the Egypt Nutrition Institute, Cairo with the Universities of Arizona and Kansas and Purdue University; the University of Nairobi, Kenya with the University of California at Los Angeles; and the Instituto Nacional de Nutricion, Mexico with the University of Connecticut. Funding was accomplished by a grant awarded to the University of California, Berkeley, which provided administrative support and technical oversight of the implementation of the research protocols chosen by the host country and US investigators.

The goal of the Nutrition CRSP was to test the hypothesis that food intake is causally related to functional outcomes that are believed to have import for the development of individuals, households and communities. A key design consideration was that this overall hypothesis, and its several specific sub-hypotheses, should be examined in different biological and cultural ecosystems, so that the findings would be generalizable.

Field Sites.

Three field sites were selected:

- Kalama, Egypt is a periurban community whose economic developmental transition is well underway; the population has access to public transportation and to modern technology, and it benefits from extensive governmental food subsidies. Almost all of the women are undereducated. The irrigation canal, which dominates the local geography, is a potential source of disease. The diet, based on wheat and rice, is varied with seasonal vegetables and fruits, fava beans, lentils and animal products.

- The population of the Solis Valley, Mexico appears to be somewhat less modernized than Kalama, but it does have electricity and television, safe water, access to public transportation and health care facilities, and a majority of its women are literate. It is a community in transition, destabilized by male absence for wage labor in urban areas but still heavily invested in agriculture. Its staple foods are maize tortillas and beans and, uniquely, a mildly alcoholic beverage is a significant contributor to the energy supply of almost all adults and some older children.

- The people of Embu, Kenya are clearly the poorest of the three, the most agricultural and, hence, the most at the mercy of the weather. Most of the population have an opportunity to attend school, but still, substantial numbers have limited reading ability; health facilities are reasonably good , but transportation is difficult to impossible. They do not have convenient, safe water or electricity. Maize meal and beans are the most common foods, but sorghum, potatoes, green banana and cow peas are also staple items of diet.

Research Plan.

A unique aspect of this research is that food intake was measured with sufficient frequency and over enough time to be a valid representation of individual and household intake. Past studies have usually accepted body size as a proxy for nutritional status without establishing the extent to which food intake accounted for differences in size. CRSP projects intended to close this gap by recording body size and fatness in conjunction with food intake.

The final research plan was narrowed to focus on three key functional outcome measures: morbidity at the individual and household level; cognitive and behavioral performance; and reproductive outcome. Measures also were taken of explanatory and potentially intervening variables, such as activity patterns, basal metabolism, socioeconomic status and sanitation/hygiene. Records were kept of temperature and rainfall, food prices and other factors deemed important in a specific location.

Participant households were chosen based on the presence of one or more target individuals: a woman in the first trimester of pregnancy, an 18-month-old toddler, or a school-age child of seven to eight years. The goal was to provide twelve months' of data on each target child and his or her parents (the lead male and female in the household). The mother-child pair was studied during months four through nine of pregnancy and first six months of the infant's life, the toddler from 18 to 30 months of age, and the schooler for one year. Limited data were also collected on non-target individuals residing in the household.

Collection schedules included weekly morbidity measures, monthly food intake (2 consecutive days per month, with intakes of energy, protein, fat, carbohydrate, animal protein and iron calculated for each day), monthly anthropometry, monthly observations of selected activities of the lead female, quarterly metabolic rate, semi-annual cognitive tests and behavioral observations on children, and semi-annual clinical examinations. Longitudinal data were collected in 1984 and 1985, based on results of pilot tests of methodology and ethnographic studies in 1982 and 1983.

Selected Findings.

Food intake differed substantially among the three projects. Average energy intakes were adequate in Egypt (assuming normative activity of children and light activity of adults) and in Mexico (assuming moderate to heavy adult activity) but not in Kenya. Kenya suffered a period of food scarcity due to a drought during 1984. Intakes were exceptionally low in that period, but intakes during the non-restricted period also were very low.

Intakes of energy and total protein were strongly related. Protein provided 11-13% of calories and average intakes easily met international standards, even in Kenya. If content of animal protein is taken as a measure of quality, the Egypt diet was clearly better than the Mexico diet, and very much better than the Kenya diet. (Percentages of protein from animal sources were 46, 28 and 14, respectively.) Nutrients provided by foods of animal origin would vary similarly.

The period of food restriction in Kenya provided an unexpected opportunity to examine the hypothesis that there is metabolic adaptation to chronic food restriction. Although adults lost weight during this period, there was no evidence of "cost-free" adaptation through a decrease in resting metabolic rate (per kilogram of body weight) or through a decrease in the energy cost of performing tasks. There was evidence that physical activity was reduced when the need for energy was increased due to pregnancy at the cost of diminished care of the household.

Growth in children began to falter early in infancy, at about three to four months of age. Although birth weights were only slightly lower than those of US children, children on average were below the 25th percentile of US norms for height and weight by six months and even lower by 18 months. After this early faltering, children appeared to grow at a normal rate for their reduced height and had reasonably normal weights for height. However, children never caught up to reference heights, and adults were below norms for height in all three projects. Kenya adults were notably thin but others approximated reference weights for height.

Across all ages, parental size and diet quality measures predicted the size of their own children, relative to other children included in the study. Maternal size was closely related to infant birthweight.

Food factors associated with infant growth were maternal energy and protein intake during pregnancy. Toddler height was weakly associated with toddler intake of animal protein and fat. These associations were significant in Kenya and Mexico but not in Egypt.

The diseases of early childhood were frequent and severe in Egypt, Mexico ranked second, and Kenya a distant third. Since food energy availability was not likely to be limiting in Egypt and Mexico, and it was in Kenya, an explanation for the differences must be sought elsewhere, perhaps in environmental sanitation, parental behavior, and/or the health care system. It is, however, noteworthy that episodes of disease nearly doubled during the period of food scarcity in Kenya.

Diarrhea had an adverse effect on the rate of weight gain in Egypt infants and Mexico toddlers, but morbidity did not account for the unevenness of growth among the Egypt toddlers, where disease was most severe. Illness was shown to depress food intake of Kenya toddlers.

Body size was a consistent indicator of psychological functioning in the newly born and in toddlers. Size was still a marker in schoolers in Kenya and Mexico. To the extent that food intake affects growth, it will affect mental function. Food intake also was specifically related to child behavior (vocalization, activity) in areas related to cognitive development.

On the average, there was no increase in food intakes during pregnancy, but the amount of weight gained during pregnancy varied with energy intake in Kenya and Mexico. Increases in maternal food intake during lactation were less than half the requirement for adequate breast milk production during the first three months in Egypt and Mexico, and were inadequate in all projects during months three through six. Supplementary infant feeding of the kind and amount given was not sufficient to make up for the deficit between maternal intake and infant needs.

Conclusions and Their Implications.

In these environments, the size a person was destined to be was determined early. Stunting was established in the first year. The population averages mask substantial variability, of course, and it is this that ultimately may allow identification of factors that associate with growth.

One might well ask why there is concern about early growth if growth is relatively normal after 12 months, albeit with a lower starting size at 12 months. The answer has to lie in the fact that there are numerous associations between achieved size and measures of functional capacity and performance. There is at least a reasonable supposition that many of these are associates of the situation that produced growth failure rather than consequences of body size itself. Further analyses of the CRSP data sets can, in all likelihood, better establish the nature of the associates of growth failure and their causative role; at minimum, such analyses can help to define more closely the "households at risk".

On the evidence of recorded low energy intakes of all target groups and general thinness of the Kenya project population, we conclude that food availability and energy intake were limiting in Kenya. Using the same criteria, this appears not to have been the case in the Mexico and Egypt projects. (That is not to say that all individuals ate enough in Mexico and Egypt, but food shortage was not characteristic of these populations.) It follows that associations with energy intake would be most readily detectable in the Kenya data set.

Infants as a group may have been food-deprived in all three locations. While there is no direct evidence of lactational failure, the indirect evidence is persuasive. Women's food intake did not increase during pregnancy and they gained much less weight during pregnancy than is customary in more privileged populations. While their infants were somewhat lighter than reference populations, the difference in pregnancy gain mainly reflects a deficit of maternal tissue reserves that otherwise could be drawn upon to support lactation. Women increased their energy intake during lactation, but not by enough to provide the amount of breast milk needed for adequate infant growth. Sustained infant growth would depend on early and nutritionally adequate

supplementation. This was not provided in sufficient quantity anywhere and the quality was especially poor in Egypt.

We are persuaded that inadequate lactation was an important cause of early growth retardation in all projects, but the situation is complex in Egypt. Women in Egypt had more body fat than the others and, on average, they gained a small amount of weight during the first six months postpartum when they could have drawn on body tissue to support lactation. This suggests that lactation was diminished because infant demand for breast milk was reduced. Two factors could have affected demand -- early supplementation with sugar-water and severe morbidity. Dilution of the quality of intake could limit growth. Infants who were ill are likely to have had reduced food demand.

A second puzzle is why children did not catch up in growth at later ages, when they had access to family food. There was only marginal improvement in relative standing between toddler and schooler ages. The proportion of fat and animal source protein in the maternal diet, an indicator of the household situation, was significantly related to attained height and weight of both toddlers and schoolers in Kenya and Mexico, but not in Egypt.

Projects have reported some relationships between morbidity and toddler growth but these are neither striking nor consistent. Because illness often affects food intake, there is an inescapable circularity in attempting to assign causality either to illness or food intake. Morbidity was more often associated with size per se than with growth, with smaller and thinner toddlers being at higher risk of serious illness. Once a child is small, however she or he arrived at that state, the reserve capacity to deal with repeated significant illness was diminished.

The search for food effects on the selected outcome variables is complicated because of the strongly interrelated nature of the variables of interest and by the fact that an individual's food intake is more uneven from day to day than is the intake of the members of a like group on a given day. There may be real relationships that cannot be proved statistically. Despite this difficulty, it was shown that intake did affect functions of interest and certain behaviors that contribute to satisfactory outcomes.

There is evidence that the nutritional quality of diets consumed by segments of all three populations is substandard. No cross-project analysis of vitamin and mineral intakes has yet been undertaken. Each project has, however, shown that essential nutrients are at risk based on biochemical evidence (vitamin B-6 in Egypt, vitamin B-12 in Mexico) or clinical signs (B-complex vitamins in Kenya). The diet quality markers that emerge frequently, if not strongly, among the few so far examined are fat and foods of animal origin. These associations are likely to be indirect. Both fats and foods of animal origin would improve the energy density of the diets, perhaps making it possible for children to obtain more calories in a tolerable volume. Both factors would also improve the palatability and variety of the diet, possibly stimulating consumption of total food. Animal source foods could exert an effect in a more specific way, by providing essential nutrients otherwise low in the diet. The probability is low that the effect is due specifically to protein (or amino acids) because total protein intake was well above accepted standards. The search for effector nutrients would be aided by improved knowledge of the composition of foods consumed, but further analyses, even with the information at hand, should provide a sound basis for intervention research.

The quality of CRSP diets, as measured by the abundance of fat and animal source protein, is positively related to the economic and social status (SES) of households. Households of higher SES are also more hygienic and are headed by more educated and/or literate adults. A major biologic reason that growth, health and development are related to SES -- a widely observed phenomenon -- is that economic sufficiency allows provision of enough nourishing food and social awareness informs the decision-maker about management of the household.

The principal decision-maker as to infant and toddler feeding and care is usually the mother. A mother generally acts in the infant's best interest as she sees it. In Egypt, where enough food is available and governmental intervention attenuates economic effects, one answer to early growth

failure is likely to lie in the education of women. The situation of women was not ideal anywhere -- Mexico project refers to the restriction of information to women, beyond formal education concerns, and many Kenya women had minimal literacy skills -- but Egypt stands out: almost all Egypt women were deprived of schooling and only some ten percent could read and write.

The most consistent predictor of children's sizes, across all ages and the three projects, is the size of parents, particularly the mother. Whatever factors constrained parental growth are persistent in these cultures. CRSP findings show the special importance of total food intake at the beginning of life. Experimentation in animals indicates that it is necessary to feed a first generation to show reproductive improvement in a second. Intervention to improve food supply in Kenya and Mexico is needed. Programs everywhere need to emphasize the need for extra food during pregnancy and lactation and inform women as to the kind and amount of foods infants need to supplement breast milk. Everyone, but particularly women, would benefit from more and better education.

TABLE OF CONTENTS

Acknowledgement i

Preface iii

Summary v

List of Tables xi

List of Figures xii

Introduction 1

Administrative Arrangements 1

Conceptualization of the Research 3

Field Sites 3

The Project Research Organization 10

Final Research Plan 10

Methods 12

Findings 19

- Foods Consumed 19
- Energy Balance 19
- Nutrient Considerations 33
- Body Size 36
- Illness and Health 45
- Cognition and Behavior 51
- Determinants of Growth and Attained Size 55
- Pregnancy, Lactation and Infancy 59

Overall Conclusions and their Implications 68

Possibilities for Intervention 70

Epilogue: Strengthening Institutions 71

Appendix A: Basic Variables List

Appendix B: Partitioning of Variance in Dietary Data

Appendix C: Sample Growth Plots for Egypt Toddlers

Appendix D: Examination of Growth Patterns in Egypt, Kenya and Mexico

LIST OF TABLES

1. Number and Composition of Households Enrolled and Number of Subjects in Cross-sectional and Longitudinal Samples 18

2. Sample Diets of a Mother and Toddler Pair in Each Project 20

3. Energy and Nutrient Intakes 22

4. Iron Intakes and Indicators of Iron Nutritional Status in Egypt, Kenya and Mexico 34

5. Body Weight and Stature 38

6. Average Observed Z Scores for Weight and Height at Selected Ages 42

7. Average Incidence of Specified Disease Categories Among Longitudinal Infants and Children in Egypt, Kenya and Mexico 48

8. Mean Duration of Illness Episodes 49

9. Comparison of Frequencies of Application of Severity Codes by Target Type 49

10. Cognitive Scores for Adults and Schoolchildren 54

11. Predicted Change in Size Parameters per 100 Kcal/Day of Usual Diet 56

12. Proportion of Size Variance of Children Explained by Maternal and Paternal Height and Weight 57

13. Maternal Age, Parity, and Birth Interval 59

14. Maternal Height and Weight During Pregnancy and Lactation 61

15. Nutrient Intake of Pregnant and Lactating Women 62

16. Nutrient Intakes of Pregnant and Lactating Women According to Coincident Food Scarcity in Kenya 64

LIST OF FIGURES

1. Organization and Management Structure of the CRSP 2

2. Location of Project Field Sites in Egypt, Kenya and Mexico 9

3. Histogram of Distribution of Energy Intakes of Toddlers 23

4. Histogram of Distribution of Energy Intakes of Schoolers 24

5. Histogram of Distribution of Energy Intakes of Adults 25

6. Comparison of Energy Intakes and Resting Metabolic Rates for Adult Males Before, During, and After Food Shortage in Kenya 27

7. Resting Metabolic rate for Adult Women by Reproductive Status in Mexico and Kenya 28

8. Z Scores for Average Weight, by Age and Country 39

9. Z Scores for Average Height, by Age and Country 40

10. Z Scores for Average Weight for Height, by Age and Country 41

11. Median Body Mass Index for Adults, by Age, Sex and Country 43

12. Percent of Sample above 50th Centile for Weight and Height, by Age and Country 44

Just as in war, malnutrition casualties should be counted not only by deaths, but also by the "wounded" people.

-- Adolfo Chavez

Quotation from Chavez, A. et al. Ecological Factors in the Nutrition and Development of Children in Poor Rural Areas. Reprinted in La Desnutricion y La Salud en Mexico. C. Perez Hidalgo y A. Chavez, eds. Division de Nutricion, Instituto Nacional de la Nutricion. Mexico City. 1976.

INTRODUCTION

Malnutrition so severe as to cause lasting disability and death occurs throughout much of the Third World. Stunted and wasted bodies are but the visible evidence of extreme food deprivation. Severe malnutrition affects human function in all aspects of life - in mental and physical capacities, in disease experience, in reproduction, and in social relationships. Where malnutrition is visible, there are vastly larger numbers of persons who are not evidently affected but who teeter uneasily on the brink. They live on the margin, with limited ability to improve their state or to affect the course of their own lives, threatened always with the prospect that some uncontrollable circumstance will push them over the edge.

The condition of less-than-severe malnutrition has received remarkably little attention. Its costs and outcomes are largely unknown, which handicaps the ability to deal with its remediation. The research reported here was undertaken to learn what the costs and outcomes are, to answer the question "What difference does it make, to individuals and to society, for families to live under conditions of chronic food deprivation?"[1] This Collaborative Research Support Program (CRSP) was designed to assess an array of human functions, addressing the question posed in policy-relevant terms, and in different geographic and cultural settings so as to allow generalization of its findings to wider populations.

The Nutrition CRSP was funded by the United States Agency for International Development (USAID), as are other CRSPs, under the provision of Title XII of the Foreign Assistance Act.[2] The intent of Title XII is that United States scientists engage with their counterparts in host countries to undertake research on the persistent problem of world hunger and, in doing so, improve the capability of the partner countries to tackle the problem independently. Thus a second purpose of the CRSP was to strengthen the nutrition research capacity of the host countries and the effectiveness of American partnership.

Each of the country projects has submitted to USAID a final report of its own work[3] What follows here is an overview of the research findings from an ecologic, cross-project perspective, and some thoughts on the policy implications of the results.

ADMINISTRATIVE ARRANGEMENTS

The projects included in the CRSP were selected by a peer-review process in open competition among eligible US institutions under the terms of a previous USAID grant.[4] The highest-rated proposal in three of the four USAID geographic regions was funded:

- Purdue University, the University of Arizona and the University of Kansas, with the Nutrition Institute, Cairo, Egypt.
- University of California, Los Angeles and Berkeley, with the University of Nairobi, Kenya.
- University of Connecticut, with the National Institute of Nutrition, Mexico D.F., Mexico.

---

[1] This question, more elegantly framed, was identified by the NAS's World Food and Nutrition Study as meriting the highest priority for research directed to problems of world hunger. See the report World Food and Nutrition Study: The Potential Contributions to Research, chapter 2. High Priority Research. National Academy of Sciences. Washington, D.C., 1977.

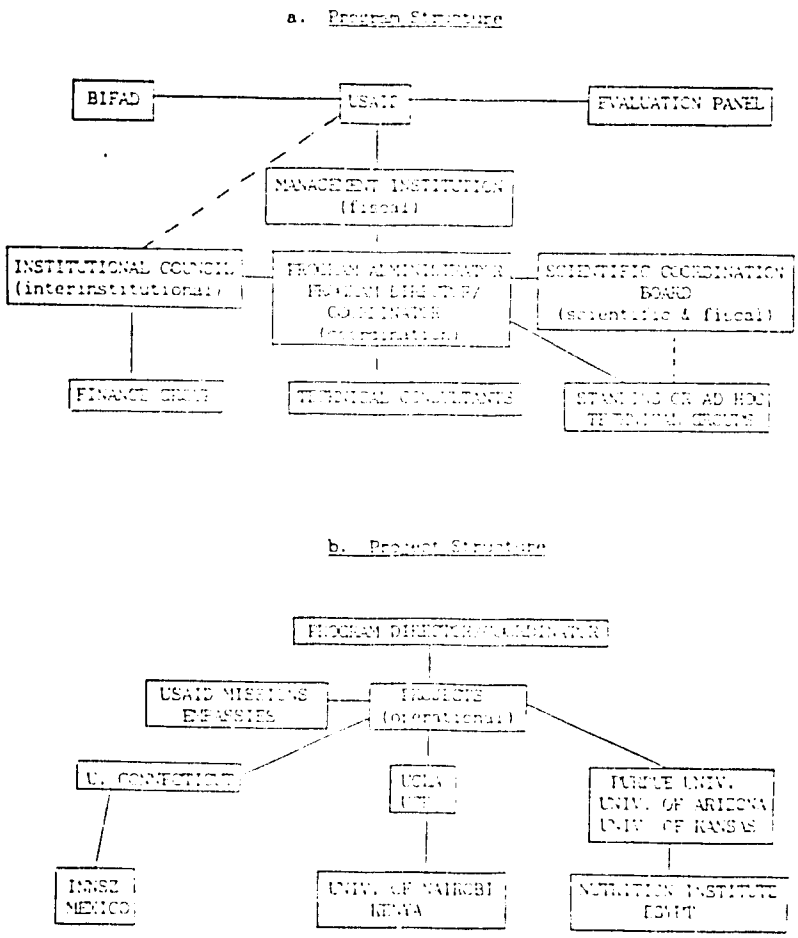
[2] Title XII is embodied in the Findley-Humphrey Amendment to Public Law 94-161, Dec. 20, 1975; often referred to as the Famine Prevention and Freedom from Hunger provision of the Act.

[3] Reports of Egypt, Kenya, and Mexico projects and the managing institution (University of California, Berkeley) on grant no. DAN-1309-G-SS-1070-00 are available through USAID or interlibrary arrangements with UCB (Call No. TX360 C84 1987).

[4] See Calloway, D.H., C. Wood et al. Final Report: Collaborative Research Support Program on Intake and Function, Contract No. AID/DSAN-C-0002, University of California, Berkeley, 31 May 1980.

The University of California, Berkeley (UCB) was chosen to be the Management Entity (ME)[1] and discontinued its involvement with the Kenya field work. The ME provided administrative support, with the advice of an Institutional Council representing the collaborating US institutions, and technical oversight of the implementation of the research protocols. All protocols were agreed upon by the participating host-country and US investigators sitting as a Scientific Coordination Board (SCB). The UCB Committee for the Protection of Human Subjects received and reviewed all approvals and materials relating to CRSP research work involving human subjects conducted by the US and overseas institutions. The scientific merit of the projects and program was evaluated periodically by an interdisciplinary group of external experts (the External Evaluation Panel), who reported to USAID. Administrative structure of the program and projects is displayed in Figure 1.

Figure 1. Organization and Management Structure of the CRSP.



[1]Guidelines for the structure of CRSP's were developed by the Joint Committee on Agriculture Research and Development, recommended by BIFAD and approved by USAID. Administrative arrangements of the Nutrition CRSP were patterned on these guidelines. The membership of the Institutional Council and the External Evaluation Panel and discussion of responsibilities can be found in the ME Final Report.

CONCEPTUALIZATION OF THE RESEARCH

As an outcome of the earlier planning activities, conceptualization of the CRSP research and a skeletal research design were in place before the CRSP was implemented. Important to its conceptualization was the general agreement on several key points, reached by the more than 100 scientists from developing and developed countries who participated in the planning:

1. Deprivation of one individual affects the state of others, that is, the effects of impaired nutrition resonate through families, communities and nations. Thus, the research was to focus on households, and individuals within them, to identify the web of interaction that results in malfunction of families and, hence, society at large.[1]

2. The most common form of malnutrition is due to insufficient intake of food overall, expressed in aggregate as insufficient intake of energy. Thus, the subject of study was to be the functional effects of sub-standard levels of food-energy intake in the range of mild-to-moderate deprivation.

3. Information on food intake is required to isolate the role of food from that of other environmental factors and as a guide to food-oriented policies and programs. Most studies have used anthropometric measures (height, weight) as a proxy for nutrition, but growth and body size reflect the combined effects of nutrition, genetics, disease experience and the like. Thus, quantitative information was to be gathered on the food intake of individuals and households, over sufficient time to be representative of usual intake.

4. The functional domains most likely to be affected by nutritional state are disease, reproduction, activity, cognition and social behavior. Thus, outcome variables were to be designed to capture information in these areas.

5. In order to be generalizable, rather than specific to a geographic, cultural or national situation, the research design must permit analysis across, as well as within, projects. Thus, each project was to gather a core of comparable data, collected at the same frequencies and by the same methods.

FIELD SITES

Once inter-institutional arrangements were in place (by 1982), preliminary field work began in each of the host countries to prepare for selection of the communities for study. The field sites were selected by the host country investigators in collaboration with US investigators. Ethnographic and demographic surveys of varying completeness were undertaken with the intent of ensuring that the communities chosen for the study contained the following elements: sufficient numbers of households and "target" individuals (sex and age categories); the requisite representation of levels of mild-to-moderate malnutrition for each target type; promise of relative population stability over the period of study; relative homogeneity in religion and language; presence of the infrastructure needed within the community to support the complex research operation; and willingness of members of the community to participate in the study. Reasonable proximity to the country's capital proved to be an attractive feature in providing convenient access to the laboratory and computer capabilities necessary to support the study. (See Figure 2.)

---

[1] In the final design, emphasis on the household as a unit was reduced. See below.

Kenya.

The community selected for the Kenya project was the Kyeni South Location in the Embu district, located in Central Kenya, 160 kilometers northeast of Nairobi, on the southeastern slopes of Mt. Kenya. Within Kyeni South Location, the study was conducted in three sublocations: Kathanjure, Karurumo, and Kathunguri. These three areas were divided into four clusters for logistic purposes. The Kyeni South Location falls within the upper and lower zones of the Kenya highlands. Kathanjure and Kathunguri are in the upper zone, with an altitude of approximately 4,000-5,000 feet above sea level. The lower zone, in which Karurumo and part of Kathunguri are located, is at an altitude ranging from 3,000 to 4,000 feet.

Ninety-eight percent of the population of this area belong to the Embu tribe, which is part of the larger Bantu group. Almost all of the Embu speak Kiembu as their first language and many have proficiency in Kiswahili, Kikuyu and English. There are, as of the last census (1979), approximately 180,000 Embu in total; over 11,000 in the study area. Most of the population is young; over half of all Embu are under age 15 The population is about equally divided between Protestant and Catholic religious affiliations.

In Embu, January, February, and October are the hottest months averaging a maximum of 24 degrees Celsius, while June and July are the coldest, with an average minimum of 12 degrees Celsius. There are two rainy seasons: the "long" rains from March to May and the "short" rains from October to December. The average rainfall differs significantly between the upper and lower zones of the region; approximately 1000 mm in the upper zone and 550 mm in the lower. The long rains failed to materialize in 1984, the first year of the CRSP main research study. The community was confronted with the consequences: failure of crops, food scarcity, selling of possessions and incurrence of debt.

Because the soil is fertile, the Embu produce both subsistence and cash crops. Their principal subsistence crops are maize, beans, millet, sorghum, arrowroot, bananas, potatoes and cassava. For cash, they produce primarily coffee, tobacco and cotton. They also own livestock, such as cattle, goats and chickens, which are a form of capital and may be eaten or sold in times of drought or other famine-threatening periods.

The Embu also earn money through wage labor, doing agricultural work or seeking local employment in carpentry, tailoring or service capacities. Another cash-earning opportunity lies in marketing local or home-made goods within the district. Cash labor does not contribute significantly to migration. In 1983, less than 7% of male heads of households spent time out of the community, for work or any other reason.

Centralization is characteristic of the present political economy in Kenya. Governmental boards regulate the marketing of all major crops with a goal of stabilization of both returns to agriculture and consumer prices. The Embu farmers rely on government/corporate institutions to organize the marketing of their cash crops. The Kyeni South Location community has established government-sponsored school systems, receives health care from both government and local health services, and maintains a system of feeder and access roads both locally and with the help of the Ministry of Transportation.

There are twelve schools in Kyeni South Location, three secondary and nine primary. Though they are government-sponsored, they receive great support and participation from the local community, and fees are charged for attendance. There are also two Village Polytechnics for those who have finished their formal education and wish to learn a trade, such as carpentry or mechanics.

Most adult males have had some education. In the study population, while about one-fourth could neither read nor write, about half had competency at some elementary school level and about one-fourth met high school standards. Adult women were less educated. One-half of the sample could not read or write, although only about one-fourth had never attended school; fewer

than one-fourth met high school reading standards. The literacy level is destined to improve if school attendance is an indicator; in the Embu district, over half of the persons aged five to 30 years were currently attending school at the time of the study.

The Ministry of Health provides care for about 5,000 outpatients per month through the Karurumo Rural Health Training Centre. The other main health care facility in the area is the 150-bed Catholic Mission Hospital. Both facilities provide a wide range of health care but refer serious illnesses to either of two hospitals located approximately 25 kilometers away.

Kyeni South Location is by no means thoroughly modernized. The community is still without electricity, telephone or postal service; away from the main Nairobi-Embu route there are no hard-surfaced roads. In 1972, a major community water project servicing 15,000 households was completed, water supply is, however, severely limited and not available inside the houses.

Mexico.

The Mexico project site was located in the Solis Valley in the governmental region (municipio) of Temascalcingo. Six communities within the region constituted the study area (San Nicolas, San Miguel, San Antonio, Cerritos, Calderas and San Jose: the last two were added to the study in July,m 1984 and April, 1985, respectively.). The municipio is located about three hours driving time northwest of Mexico City, in the Central Highlands of Mexico, and has an elevation of approximately 2500 meters at the valley floor and 3000 meters in the surrounding hills.

The town of Temascalcingo is the principal town of the municipio. There is a bank, a hotel, a busy bus station and many commercial activities, including the large market that takes place on Sundays. There are paved roads between Temascalcingo and some of the villages. Increasing numbers of private automobiles are on the roads as well as commuter buses taking people to work and the markets. The valley also has an extensive, newly reconstructed irrigation system that routes water throughout the valley floor.

Almost all households, excepting those on the poorer, upper slopes, have a faucet outside the house through which water from a community well is pumped. When the pump breaks down, a frequent occurrence, water must be carried from the well. Almost all homes also have electricity and over half have television sets.

The population of the Temascalcingo district is approximately 44,000, made up of Mestizos (mixed European and Indian) and Indians. The Mestizos live mostly in the bottom of the valley, the Indians mostly in the hills. The religion is predominantly, but not exclusively, Catholic.

There is a variety of health care facilities for the people in the region. There are two state-funded health centers, which are moderately priced, and four federally funded centers, which are free. There are twelve private, full-time doctors in the town of Temascalcingo and one part-time doctor in San Nicolas, one of the study communities. Their fees are significantly higher than those of the health centers. The people of the municipio also rely on traditional practitioners for certain medical needs, such as midwifery and bonesetting. The Indian community tends to use traditional methods of healing more regularly than does the Mestizo.

The Unidad Medico Social is a hospital in the town of Solis that is sponsored by a myriad of different federal and state agencies. The hospital has a few beds for adults and children, cubicles for newborn infants, a delivery room, and x-ray and laboratory facilities. It served as the headquarters for the Mexico CRSP project.

The climate of the municipio of Temascalcingo is like that of most of the Central Highlands; moderate in the summer and quite cool in the winter, with temperatures ranging from three degrees Celsius to nearly 30 degrees Celsius. The rainy season, as in most of Mexico, lasts from late May or early June through the summer.

The Solis Valley and its people were once dominated by a large plantation (now called the ex-Hacienda Solis), whose land was redistributed under the land reforms following the 1910-1917 Revolution. The main crop was wheat prior to the land redistribution; afterward, maize became, and still is, the primary subsistence crop but wheat, rice, beans and squash also are produced. The federal government, through its Systeme Alimentaire de Mexico, is involved in the marketing of maize, wheat and beans; during the time of the CRSP, when the financial condition worsened in Mexico, the subsidy was directed principally to aid the lowest income consumers. In the Solis Valley, families consume their own crops to a large extent but have to rely on purchased staples for several months each year. Households both produce and purchase pulque, a "beer" made from agave juice. Most other food products, such as fruits, vegetables, cheese, bread and sweets, are purchased from the large market vendors that come to Temascalcingo every Sunday. The people of Solis also participate in non-farming work, including pottery, basketmaking, metal-working and brick manufacturing.

Many farmers have found that the yield from farming is not enough to survive; so they must hire themselves out as wage laborers. Others see wage labor as an opportunity to improve their standard of living. In the Solis Valley, this situation has resulted in heavy labor migration of the male population. Fifty percent of the adult men in the community work outside of the area, primarily in Mexico City. Since Mexico City is three hours driving distance, most of the men must be absent from the home for the better part of the week, usually returning to spend the weekend at home. Many also remain in Solis during the peak periods of agricultural work demand, but generally their tasks fall to other members of the household or to hired labor.

The structure of the educational system is another reflection of Mexican economic and social development. In the past decade, each town in the Temascalcingo region has established a community primary school. The town of Solis also built a secondary school. This recent expansion of educational resources in the valley reflects a relatively new attitude of the people towards literacy and education. Approximately 80% of parents in the study sample expected or desired their children to be educated beyond the primary levels. Most of the parents studied, however, had achieved relatively low levels of education. Only six percent of the men and three percent of the women in the study had over six years of schooling, and about one-fourth of the women had little or no ability to read and write.

Egypt.

Kalama, the site of the Egypt project, is a town of about 1500 households, covering approximately 1,830 acres. It is located in the Nile Delta, not far north of Cairo, and just off of the main Cairo-Alexandria highway. The land is extremely flat, with no hills or mountains.

There are three distinct seasons in the Nile Delta -- the hot and humid summer from April to August, the mild autumn from September to November, and the cool winter from December to March. Rain falls only in the winter, usually no more than six times a year, in brief showers. The rest of the year the weather is hot, with an average temperature of 22 degrees Celsius and an average humidity of 62 percent.

One of the geographical landmarks of Kalama is the canal that snakes its way through the village. It is important to community social life, serving as a gathering place for the people, primarily the women, as they complete their chores at the waterside.

There is one health center in the village, which provides a variety of health care for the people of Kalama. The staff includes a general practitioner, two dentists, five nurses and 16 associates. Both inpatient and outpatient services are performed, with special services designed for mother/child care and family planning. Private medical care is also available in Kalama, including two physician-run clinics, two pharmacies, four lay midwives and five lay health attendants.

Kalama is far less rural in character than the Mexican or Kenyan communities. Many Kalamans work in Cairo and many Cairenes have moved to Kalama because of the housing shortage in Cairo The

village itself seems to escape the fast pace of the highway setting, yet it is experiencing a socioeconomic transformation because of its proximity to a major urban center.

Kalama is a fully electrified village, both indoors and outdoors. About 10% of the homes have an indoor water supply, another 10% have water pumps near their houses. There are both traditional and modern homes in the village. Family dwellings are primarily two-story brick houses or one-story adobe, adobe-brick, or brick houses. The more modern homes have a separate shelter for the farm animals, and most families have electric appliances. Two-thirds own television sets, half have washing machines and 10 percent own refrigerators.

As the village has become more modernized, the people have chosen more commercial occupations. No longer is agriculture the sole means of subsistence. About 21% of the study households were employed only in agriculture and 23% were involved with both the agricultural and non-agricultural sectors. Over one-half of the families in the study were non-farming families. Among the non-agricultural activities, there are a significant number of entrepreneurial enterprises, such as fast food stands, television and bicycle repair shops, haberdashery, weaving and photography. Also, many Kalamans work in Cairo in the service or public sector, i.e. sales clerk, government clerk, etc.

Kalama's political and social organization reflects the modernization of the community. The primary political body in the village, the Village Council, was founded within the past 25 years. The council is responsible for all public sector and commercial activities, such as schools, mosques and health centers, as well as poultry farms and bakeries.

Despite the apparent "urbanization" of Kalama, many social and cultural traditions remain intact. Kalama is a strongly Moslem community, which adheres to the teachings of Islam. This religious traditionalism is most obvious in the division of labor between men and women and in their education. Women perform the domestic work, while the men provide financial support for the family. Education for women is not stressed in the society. There are five schools in the community, all built after 1955. Kalama's religious preparatory school enrolls only males. The other four allow females to attend but in significantly smaller numbers than male students. Females may be educated through the primary levels, but males dominate the secondary levels of education. Almost half of the adult male population are literate but only 10 percent of women can read and write.

Agricultural production remains a strong economic force, despite the transformations described above. Most of the farming is done on many small farms. The Egyptian Reform Laws of 1969 set a maximum limit on the amount of land an individual or family can own, so by 1975, the average land holding was 1.5 feddans (1.56 acres). Most farmers grow a variety of crops according to season, profit-potential, and seed and labor availability. The principal food crops grown are maize, beans, parsnips, carrots, leaf crops and other vegetables. In the summer, farmers grow tropical fruits, such as watermelon and mangos. Dates are grown in the autumn, and in the winter, citrus fruits are produced. Given the scarcity of rain, flood irrigation is crucial to farming. Kalama also produces goat-milk cheese.

The Egyptian government subsidizes certain staples -- sugar, rice, flour, bread, lentils or fava beans, cooking oil and tea -- and cooking fuel which stabilizes their price and availability. There is also a rationing and price-support system involving frozen meat and some canned goods.

Comparison of the Three Sites

The three CRSP locations thus are seen to differ in important ways. The intended spectrum of climatic and cultural variations is represented in the program, but there are also major differences between projects in terms of political, economic and development features that affect health conditions and food availability and use.

Kalama is a periurban community whose economic developmental transition is well underway; the population has access to public transportation and to modern technology in the form of television and the like, and it benefits from extensive governmental food subsidies. But Kalamans, particularly almost all of the women, are undereducated; the irrigation canal, which dominates the local geography and functions as a meeting and washing place, remains a rich source of disease, and provision of health care is uneven. The diet, based on wheat and rice, is varied with seasonal vegetables and fruits, fava beans and lentils and animal products.

The population of the Solis Valley, being more remote from a central city, appears to be somewhat less modernized than Kalama but it does have electricity and television, safe water, access to public transportation, and health care facilities, and a majority of its women are literate. It is a community in transition, destabilized by male absence for wage labor in urban areas but still heavily invested in agriculture. Its staple foods are maize tortillas and beans and, uniquely, a mildly alcoholic beverage is a significant contributor to the energy supply of almost all adults and some older children.

The people of Embu are clearly the poorest of the three, the most agricultural and, hence, the most at the mercy of the weather. Most of the population have an opportunity to attend school, but still, substantial numbers are functionally illiterate; health facilities are reasonably good, but transportation is difficult to impossible. They do not enjoy the benefits of convenient, safe water or electricity. Maize meal and beans are the most common foods, but sorghum, potatoes, green banana and cow peas are also staple items of diet.

There is no requirement, in terms of research design, that the study populations be representative of the country or district in which they were located, only that a sufficient range of the variables in question exists in the sample. Still, the study communities do seem to reflect the national situations. The Food and Agriculture Office of the United Nations[1] describes the food situation in the three countries as follows:

	Population (millions)			Dietary Energy Supply (kcal/capita)		
Country	1970	1980	%change	1969-71	1979-81	%change
Kenya	11.3	16.5	+32	2260	2012	-11
Mexico	51.2	69.8	+27	2641	2891	+9
Egypt	32.8	42.0	+28	2561	3178	+24

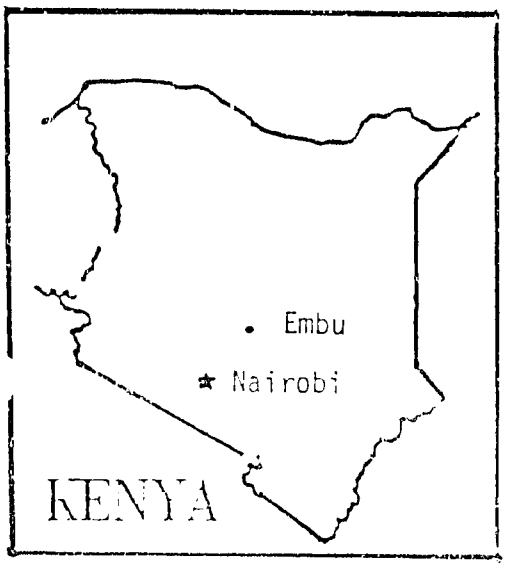
While the data on dietary energy supply have not been adjusted for the age and sex composition of the populations, they serve to indicate that the food energy situation is best in Egypt and improving; it is not quite as good in Mexico and is much poorer and worsening in Kenya. In terms of quality, as of 1977, about 64% of the dietary energy in Kenya and Egypt came from cereals, roots and tubers, and another 10% from sugar; in Mexico, these figures were 50% and 15% respectively. These figures may be compared with statistics for the United States,[2] where the dietary energy supply is about 3450 kcal/capita, only 23% of which comes from cereals and starchy foods and 17% from sugar.

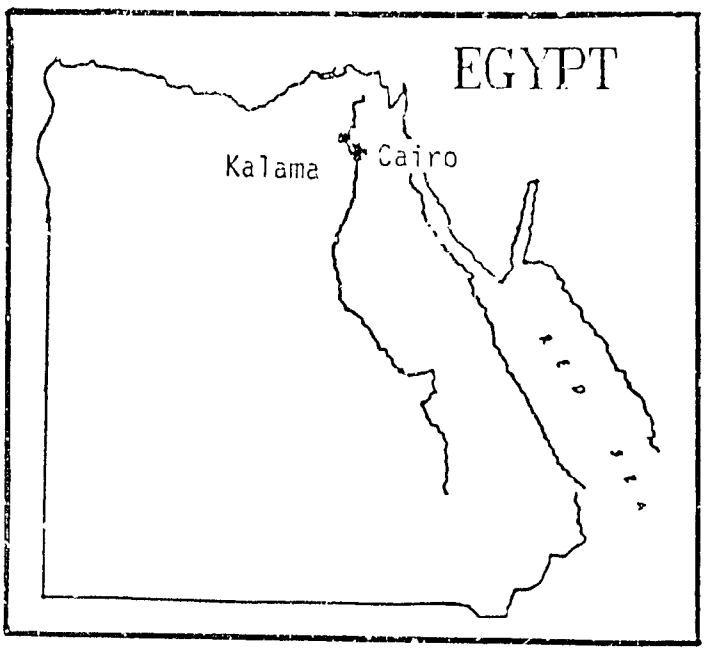
---

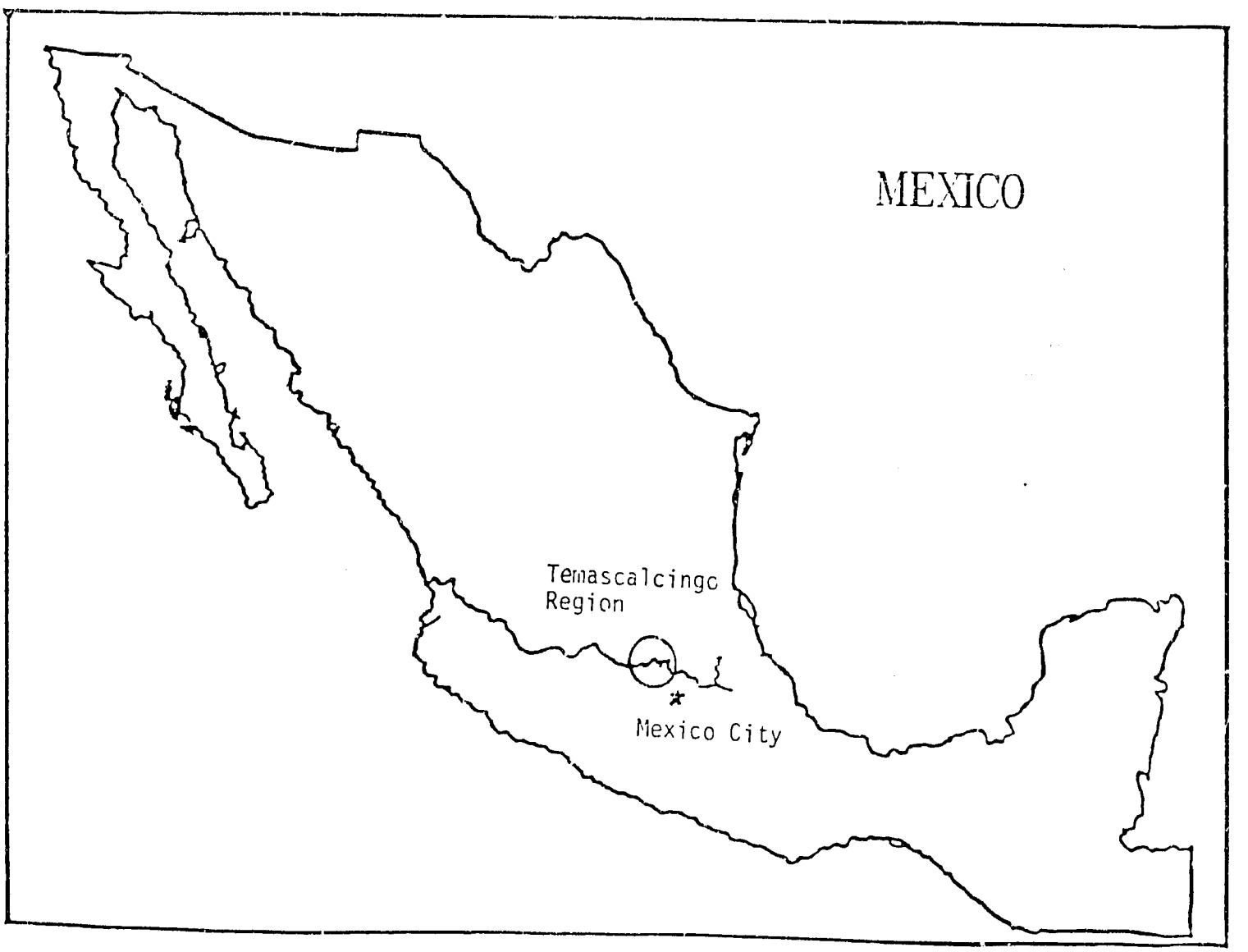
[1] FAO, Fifth World Food Survey, Rome, 1987.

[2] Data from USDA, National Food Review, Winter, 1986, pp. 6-9.

Figure 2. Location of Project Field Sites in Egypt, Kenya and Mexico







THE PROJECT RESEARCH ORGANIZATION

As the situation of the study communities varied, so did the project organization. Because Kalama is close to Cairo, it was feasible to use trained professionals for field staffing, and senior investigators were at hand at the Nutrition Institute and from the Cairo academic community. Almost all field work was carried out by Cairenes who commuted by van from the Institute on a normal work schedule. One position was filled by an American who was headquartered at the Institute in Cairo; duties of that person were largely administrative. The Egyptian staff were all bilingual, but it was necessary for the American personnel to learn Arabic, the village language.

Embu is sufficiently remote from Nairobi to make daily commuting impractical. The project set up a field operation center in Embu and, because of the size of the study area, organized four sublocations that served as rendez-vous points for field staff and where first-level data processing took place. A cadre of young foreign professionals led the field research effort. The first team included an English doctoral-level director, an American anthropologist and an American nutritionist, all of whom acquired local language competence. After three years in the field, the director and anthropologist were repatriated at their request and replaced by other American personnel. Until quite late in the study, the chief field physicians were foreign (but not all American). The field business officer was American. All other field supervisory staff were Kenyan mid-level professionals from the local area or the University of Nairobi. The approximately 150 field staff were local high-school graduates. Kenyan staff had English language competency as well as Swahili, and Kiembu, the language of the villages. The field staff, both expatriate and Kenyan, was, thus, resident in and involved with the Embu communities. The team's presence almost certainly altered the health awareness of the local population and the team provided significant health care. The project staff intervened during the drought period by helping to obtain and distribute food supplies and seed; they carried out a survey of the entire community, not just study households, to guide food relief distribution.

The Solis Valley also is too far from Mexico City to allow daily commuting. The project was generously given access to governmental clinics and laboratory facilities, office space and housing for senior personnel in the central Solis location. The project also developed and staffed small office and primary health care centers in some of the villages and set up and maintained computer files on vaccinations and the like for the general population of the study area. The field director was a Guatemalan medical doctor. Most of the other research staff were mid- or upper-level professionals, mainly Mexican, recruited by the Instituto Nacional de la Nutricion. There was substantial turnover of personnel in the early years of the project as rural living lacked appeal for many young staff. A number of field staff of the food intake and anthropology team initially were from the Temascalcingo region, but the work increasingly was carried out by the more advanced staff. All the professional and scientific staff were bilingual, including the American investigators.

FINAL RESEARCH PLAN

The CRSP research plan required the three projects to formulate hypotheses in a testable manner, and to agree on a series of scientific outcome, or dependent, variables in the functional domains of interest. Also to be agreed on were the methods by which information on these variables and on the independent variable -- food intake -- was to be obtained and recorded.

The independent variable, food intake, presents both a formidable methodological problem and one of interpretation. Solution to the how-to-measure problem must, of necessity, emerge from pilot study of food preparation and distribution in the actual communities. Interpretation of intake figures, assessment of their significance, is complicated because the adequacy of an individual's nutrient intake depends on that person's requirement.

Requirement for a nutrient may be relatively constant across time as, for example, in the case of adult needs for some minerals. Energy requirement is, however, markedly affected by physical activity (as well as body size and leanness). As activity is, to some extent, optional, it is possible to accommodate to reduced intake by decreasing the energy used for physical activity . There is

evidence that people living on low planes of intake do spend less time in active tasks or recreation and slow the pace of work performance.[1] This type of behavioral adjustment would not be cost-free if the activity reduced were important to economic productivity, household hygiene, childcare or learning. The CRSP researchers hypothesized that it is through this path that chronically low intake of one person might affect the well-being of others -- families and communities -- in addition to direct consequences to the individual him- or herself. To explore this question, the CRSP research plan was to gather information on how key adults spend their time.

It has been argued that an individual can adapt to a relatively wide range of energy intakes without altering physical activity or changing body lean and fat stores.[2] This adaptation theoretically occurs by alteration of the biochemical activity of body cells. Such adaptation, if it exists, should be reflected in the energy expended by the body at rest (basal or resting metabolism (RMR)). The CRSP research plan was to include RMR measurements on a subsample of the adult population, which could be compared with published standards.[3]

As the Principal Investigators (PIs) and consultants probed the multiplicity of questions subsumed in each of the functional outcomes of interest, a very large "wish" list of variables to be measured was accumulated. These included the principal outcome measures but also explanatory variables and variables intended to enable analysts to control for potentially confounding factors. The list was reduced after collective review by the Scientific Coordination Board (SCB) and still further based on preliminary field experience. Finally, the design was severely truncated on the recommendation of the External Evaluation Panel to focus on two "high priority, low [research] risk" functional relationships: morbidity and cognitive performance.

The approved research plan was to gather 12 months of data on selected target individuals within households, as needed to test hypotheses relating food energy intake to morbidity and cognitive performance. While this plan served to simplify the research design, the intended focus on households was largely lost as a result. Projects were free to add other measures specific to the PI's particular interests or to the research venues and arrangements, if approved by the SCB as being meritorious and accomplished within an upper limit of 15% of a project's assigned budget.

Target individuals selected for study were the conjugal pair who headed a household (called the lead male and female), and one or more of their children as follows: a "schooler", aged 7-8 years; a "toddler", aged 18 months; and/or an "infant", newly born after an observed pregnancy. Selected data were recorded for other members of the household, as well as indicators of household social and economic status (SES) and sanitation.

The research plan was designed to test six main sets of hypotheses:

1. Food intake of adults affects their morbidity, their care of and attention to children, and their performance of usual tasks, and this, in turn, affects the morbidity and cognitive and behavioral performance of other household members.

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

3. Food intake of the child between 18 and 30 months affects his/her body size, morbidity, and psychological development.

4. Food intake of the child between seven and nine years affects his/her body weight, morbidity and behavioral and cognitive performance.

---

[1] Berg, A. Malnourished People: A policy view. World Bank Poverty and Basic Needs Series. June, 1981.

[2] Sukhatme, P. V. and Margen, S. Am J Clin Nut 35:355, 1982.

[3] FAO/WHO/UNU: Energy and Protein Requirements. Technical Report Series. No. 724. WHO, Geneva, 1985

5. For adults, a reduction of resting metabolic rate provides a major path of adaptation to restore energy equilibrium.

6. Household food intake affects household morbidity.

METHODS

The array of variables and measurement-frequencies necessary to test these hypotheses is presented in Appendix A. In brief, the regular cycle of principal measurements was:

-- weekly morbidity (all members of household)
-- monthly food intake, two days per month (all target individuals and households)
-- monthly anthropometry for target individuals
-- monthly observations of selected activities of the lead female.
-- quarterly metabolic rate (a subsample of lead males, lead females, and schoolers)
-- semi-annual cognitive tests (children)
-- semi-annual clinical examinations and demographic updates
-- annual anthropometry for non-target household members

The SCB agreed on methods that were to be used to measure and record these variables. Recognizing that adjustments appropriate to field conditions would be necessary, it was nevertheless intended that measurement schedules would be adhered to and that the content of the variables would be uniform.[1] Generally, this agreement was kept, but some seemingly small deviations in methodology present difficulties in cross-project (but not necessarily within-project) analyses. The brief descriptions of methods that follows includes notation of recognized differences.

Food Intake.

A minimum of six days of food intake data is needed to provide reasonable assurance that the figure is representative of "usual" intake. Ideally, all days of the week and special fasting/feasting periods would be included proportionally in yearly intake figures -- in practice, only the Egypt project used an interview schedule that accounted fully for these days. The measurement schedule of two days per month allows aggregation of data across any three-month period of study. Many questions can be asked using this data set that do not require that food intake be "usual" (for example, "does illness affect food intake?"). For these purposes, intake data can be aggregated in other ways.

Data on household food preparation and consumption for the 24-hour period preceding the interview were collected by questioning and observing the lead female. Individual intake of target subjects in Kenya and Mexico was measured by a combination of observation (weighing by the interviewers) and recall (count of discrete items, such as pieces of bread, or volume of foods, such as stew apportioned from a household common pot). In Egypt, the intake of other household members from a common pot usually was recorded as a proportion of the amount consumed by the lead female. In all projects, the lead female reported on the intake of infants and toddlers and on foods consumed within the home by schoolers and lead males. Schoolers provided information on their food consumption outside the home, as did lead males if they were willing. Lead males were often absent or unwilling to respond; partial reports were counted as missing for hypothesis testing (but have value for other purposes). In Kenya, if the lead female was absent, the substitute food-preparer was interviewed; the other two projects rescheduled the interview if the lead female was absent or unable to respond that day. The Mexico project experienced initial

[1] The final report of each project provides details of methodology including project-specific variables. Each project prepared field manuals instructing surveyors on the prescribed methods of data collection to be followed; these manuals are included in the CRSP program archive deposited with USAID.

difficulty in implementing the food intake methodology and found it necessary to make a major change in interviewing midway through the data collection period. At present, only intakes collected with the revised methodology are being used in analyses.

Because both household and individual food consumption are known, it is possible to examine many sub-hypotheses using this data set, e.g. intrahousehold food distribution, patterns of food use, use of drought-relief foods in Kenya, etc. These analyses have not yet been undertaken by the projects or ME.

In each country, a food composition data base was required for converting amounts of foods to amounts of nutrients consumed. Each project developed a food composition data base for this purpose, built primarily on existing tables of food composition. The INN tables for Mexico required few changes, and there was a substantial amount of information available for Egyptian foods; Kenya tables had to be constructed. A small number of important local foods were analyzed under CRSP auspices to complete the data bases. All tables were converted to electronic form and now are available for use by the countries. However, much of the published food composition data for the three countries is quite old and may be inaccurate-- not only has the food supply changed in recent years, but analytic methodologies have undergone significant advances. Countries should consider updating their composition data as a top priority, and laboratories in all three of them are available to carry out this work if funded to do so.

The numbers of food items and nutrients in the tables varied somewhat among the projects. The original CRSP protocol called for a minimum of four nutrient variables: energy (kcal), protein (grams), fat (grams) and carbohydrate (grams). In addition, all projects calculated iron intakes (mg) and animal protein intakes (grams). Mexico and Egypt projects calculated intakes of several additional nutrients.

Anthropometry.

Measures of body size changes over the period of the CRSP were crucial to the interpretation of relationships between intake and functioning. Size also is one of the factors that affects nutrient requirement. Data were collected on height (or length if less than 30 months of age), weight, arm and head circumference and two skinfolds (an indicator of fatness), every month for infants and at regularly specified intervals (monthly or once every three months) for the other target individuals. To ensure data reliability, duplicate measurements were made on each occasion by two observers; when measurements differed by more than a prescribed margin, the routine was repeated. Even so, measurement errors are found in this data set, e.g. a later height measure smaller than a previous one. Reliability is best for body weight measures and least for skinfold thickness measures. Length measures of infants and toddlers appear to have substantial measurement error.

To circumvent some of these problems (and for specific analytical purposes), regression slopes based on interval measurements of length and weight of individual toddlers are used to estimate achieved size at given times between 18 and 30 months of age. The slope of the linear regression is a measure of growth rate. Quadratic (non-linear) representations of weight and length added little predictive power to the linear representations. An indirect indicator of fatness, the Body Mass Index (Weight (kg)/Height $(m)^2$) is used for cross-project comparisons of adults rather than skinfold thickness, because the data base on height and weight is much more complete.

Metabolic rate.

Metabolic rate is estimated from the respiratory gases (volumes of oxygen consumed and carbon dioxide produced) of a person lying comfortably at rest two hours or more after eating (resting metabolic rate, RMR) or after an overnight fast (basal metabolic rate, BMR). Projects elected to use a semiautomated Beckman Metabolic Measuring Cart for these measurements. An

instrument problem[1] was discovered by the Kenya project after the study period, but correction equations were developed and applied to the data set. The Kenya project also made comparison measurements of adult male RMRs with the Max Plank Respirator, an instrument that is widely used for respiratory gas studies; the data are closely correlated (r=0.8) but Beckman values are 8-10% lower than Max Plank values. The Egypt project experienced great difficulty in setting up the method and, hence, missed early data; its measurements, like the Kenya values, must be recalculated using correction equations, but this has not been done, due to lack of time and funding. The Mexico project was unable to put the Beckman instrument in working order and substituted the Max Plank Respirometer throughout the study.

Both Kenya and Mexico measured RMR of schoolers as well as lead males and females. The Kenya project also used the metabolic cart to measure the energy cost of a variety of physical work tasks. These data are of value in estimating the effect of specific tasks on energy requirement.

Morbidity.

In order to record episodes of illness, an interview with the lead female was carried out weekly. In Kenya and Egypt, and for a short period of time late in the Mexico project, structured questions about the health of all household members during the preceding week were asked, including a systematic probe to determine whether illness was present even if unreported. The Mexico project deviated from the protocol by inquiring if anyone was sick on the day of interview and following up only on illness existing on that day. Thus, illnesses of short duration (less than one week) are underreported in the Mexico data.

When an illness of a target individual was reported, information on symptoms, date of onset and recovery, dietary modifications, treatments and activity changes were recorded. For non-target individuals, only initial probing questions were asked. Interviewers were physicians in both Egypt and Mexico; in Kenya, the trained interviewers had no previous health sector experience but were supervised by a public health nurse under direction of a physician. If illness was severe, primary care was given and the patient was referred to a health center for treatment.

Diagnosis of illness was done by physicians according to categories of illness and severity. Concepts of disease and analysis of common diseases prevalent in the study area were important in structuring the questions for the morbidity survey.

Physical examination and health evaluation.

A medical history and physical examination was administered to all target individuals at the time of entry into the study with quarterly updates on disabilities and chronic conditions. Nutrition-related physical examinations were carried out every six months for all targets, as well as during the fifth and eighth months of pregnancy and the sixth month of lactation. Repeated interviews for the purpose of detecting pregnancy were done, as many women never menstruated between pregnancies; urine testing was made available if the women desired. Laboratory assessments of hemoglobin, serum albumin and transferrin were made, and routine screening of blood, urine and feces was done in each location.

Appropriate treatment was prescribed if parasitism was found, and persons diagnosed as anemic (hemoglobin level below 9 gm/dl) were given iron tablets.

Additional laboratory studies of interest were carried out by each project. Some samples of breast milk were obtained; these and a subset of blood samples were intended for the study of immune factors. Nutrition factors of particular interest to projects are: zinc and vitamin B-6 in Egypt; zinc,

---

[1]Samples were not dried before analysis; newer models of the Beckman instrument have corrected this defect.

folacin and vitamin B-12 in Mexico; and iodine (goiter) in Kenya. Work on these components is still underway or pending availability of funds.

Psychology.

Psychological function was measured according to two related dimensions, cognitive and behavioral. Cognitive aspects were measured by items drawn from tests which have been used across a variety of cultures. These tests include the Brazelton Neonatal Assessment Scale for newborns, the Bayley Infant Behavior Record, and the Bayley Mental and Motor scale for toddlers; the Wechsler Intelligence Scale for Children for schoolers ; and the Wechsler Adult Intelligence Scale for lead males and females. Structured observations of child and caretaker were devised to record physical contact, vocalization and response of caretaker to infants and toddlers. Structured observation of schoolers was carried out in the classroom and playground.

Social and economic measures.

Information on household social and economic status was collected in order to be able to assign scores to each household. Each project collected information on housing, occupation and education of lead adults, and on assets such as land, animals, vehicles and tools, which the PIs believed to be most appropriate for the construction of indexes or scales. Because each of the projects approached the problem in a different way and the communities are so dissimilar, each must be interpreted separately. What is called low or high SES may represent quite different life situations in the three places.

The Egypt project's early ethnographic work which focused on family and social structure provided the basis for designing instruments to rate households. Concentrating on instruments that would be objective while culture-specific, investigators examined household demographic structure, housing characteristics and assets of household, and occupation and formal education of target males.

The Kenya project was the only one to develop a separate "emic", or within-culture, scale where rankings were done by community leaders. Toward the end of the field project, sub-chiefs and senior indigenous fieldworkers assisted in developing hierarchical criteria of social and material success among the Embu. It is striking, but not surprising, that the locally developed scale ranks some criteria significantly lower -- occupation, for example -- than would most "etic", or outside-culture, expectations. In addition, an extensive survey instrument was used quarterly throughout the field period, asking questions about numerous variables believed to be related to SES.

Mexico has presented one scale of SES which is a combination of two subscales: CASA, a scale based on household construction items and number of rooms and beds, and MSL, a scale representing the market price value of material possessions that required cash purchase. The CASA scale is reported to have a normal distribution and the MSL to be skewed due to the presence of a few families with many possessions. The Mexico project differs from the other two projects in that it did not use education, occupation or non-material, prestige-related items. The project reports that occupation was not a useful variable, as almost all had the same two occupations (farmer and laborer).

Sanitation and hygiene.

A scale of household hygienic adequacy was constructed from appropriate measures at each field site. Specific data collected varied among projects but included quantitative measures of household contamination, bacteriological examination of water supply and structured observations of the household environment. The lead female's practices and proficiency in performing sanitary activities (hand-washing, etc.) were observed as was the physical appearance

of children, a somewhat subjective and crude, but surprisingly useful, indicator of general hygiene.

Activity pattern.

All projects carried out a series of behavioral observations of mother-child interactions that also provide some information on common activities. Each project independently undertook a separate assessment of activity as it deemed appropriate to its circumstances, much of these data are yet to be analyzed.

The Mexico project carried out two protocols designed to capture different components of time allocation/physical activity patterns. The first was a 24-hour recall of major categories of activity of a sample of lead males and females (sleep, agricultural tasks, etc.). A second study examined the distribution of activities in the family during school and vacation periods. During the period of study of mother-child interactions, activity was also recorded for 10 hours by means of a watch-like device (actometer) worn by both mother and child.

The Egypt project's pilot study of activity involved observation for 2.5 hours on one day and on the day following a recall of activities performed from 6 am to 6 pm the previous day. During the main study, a total of 10 hours of observation was accumulated for adults and schoolers in scheduled two-hour time blocks selected to include Friday, Saturday and any other days. Information was gathered on equipment used, location, social context, etc.

In Kenya, pilot study focused on observation of toddler activity patterns and recall of adult activities, but this work was not pursued in the main study because of costs in the first instance and reliability in the second. During the second year of the study, time allocation was explored by means of spot observations of chiefly daytime, weekday activities, supplemented with a smaller number of late evening (6-9 pm) and Sunday visits. Activities of all individuals present were recorded. Each household was observed a mean of 1.1 times per week throughout one year. These data allow construction of a typical pattern but not the activity pattern of any one individual.

Other measures.

Kenya and Mexico projects recorded data on environmental temperature and rainfall, and on prices, wages and major events in the communities. Mexico devoted substantial effort to on-farm study of agricultural production. Information on agricultural production/land use was also gathered in Kenya. These, and other, data are archived but have not yet been analyzed.

Data management.

Each of the collaborating projects implemented the overall data management plans in a manner appropriate to the infrastructure available to it overseas. Data for the Egypt project were recorded on field forms and recoded for data entry; facilities at the University of Kansas were employed for the first year before a computer-entry firm in Cairo was located. The Kenya project's data were entered onto computer-coded forms in the field and key entered in Nairobi by a private computer firm before shipment to the US. The project in Mexico had the interest and cooperation of a branch of the Ministry of Public Health in Mexico City, and of IBM, Mexico City. Some of the project data were entered in the field on microcomputers and taken to the Institute of Nutrition in Mexico City, some data were entered directly on the main frame in Mexico City, and some were entered at the University of Connecticut's facilities. Data tapes and documentation from all projects were copied to the University of California, Berkeley. A final archive of all CRSP files was prepared at Berkeley, deposited with USAID and copied to the PIs at each contributing institution

(US and foreign). By CRSP agreement, the archive is embargoed for further distribution until February 1, 1989.[1]

Sample population.

The PIs had agreed early on that the mother-infant pair should be a major focus, the mother being studied during gestation and the mother and child during lactation. Toddlers were selected to receive particular study because of the expectation that morbidity would be highest in this age group and because cognitive development could be assessed by change (in contrast to simply state) measures. It was difficult to decide which other children were to be studied; a child age seven to nine years was chosen finally because most would be enrolled in school at that age, boys and girls are more alike than at later ages, and they have reasonable ability to report on their own. (Investigators would have liked to include an adolescent age group but reluctantly abandoned this group because of the high variability in onset and completion of puberty and the associated biological and social changes.) The adult male head of a household was included as a principal decision-maker and because of the importance of his contribution to family welfare, notably in relation to children. Target individuals were to be members of studied households.

For the purpose of the design, certain characteristics of a family/household determined inclusion/exclusion from the sample frame:

1. Only a small proportion of non-fertile families, not actively reproducing, could be included so as to avoid inordinate increases in sample size requirements (for the reproduction component). This meant that single parents, childless households and older adults were excluded from the study.

2. Households containing members with severe nutritional or other diseases, apparent on clinical examination at the time of initial screening, would be excluded from longitudinal study.

3. Households representing atypical cultural, ethnic or genetic characteristics for the selected community would be excluded because the numbers would be too small for statistical examination.

Based in preliminary estimates of variance, it was concluded that data would be needed on about 100 individuals of each target category. For efficiency, investigators sought households that would provide multiple targets, but the number of households was necessarily two- to three-times the number of individual target subjects in each category (see Table 1). This means that the number of nontarget subjects of various ages, on whom a significant amount of data were gathered (body size, weekly morbidity) is substantial and will provide an exceptional opportunity for future analyses.

The selection of households, based on the presence, or anticipated presence, of target individuals in defined age windows, also means that there are relatively few situations in which the same household provides multiple target children -- any analyses that attempt to link such targets must do so through characteristics of households rather than by simple identification of the particular household. This is the direct result of the design decision to focus upon individuals with defined age intervals rather than households; the decision facilitates the posing of some analytical questions (about specific individuals) but greatly encumbers the posing of other questions (about households or interactions of individuals).

Because of the projects' enrollment strategies, cohorts of target subjects do not necessarily overlap in time; parents were, however, always studied during the one-year period of study of the child. Because some households had more than one special target (second trimester pregnancy plus infant to six months, toddler, schooler), some were studied well beyond one year and others

[1] A detailed description of the final CRSP archive is contained in the ME Final Report.

were not. In all cases, the pregnancy sample is the latest in time in as much as enrollment was anticipatory (i.e., the women's youngest child was ≥18 months of age) or awaited proof of pregnancy. Generally, the schooler cohort is the earliest in time. These differences present a problem where conditions changed from one year to the next, such as, in 1984, the occurrence of the drought with associated food scarcity in Kenya and a major change in food intake methodology in Mexico in January, 1985. SES conditions also may change over time, but projects generally assessed SES factors at entry and exit of a study household.

Table 1

Number and Composition of Households Enrolled and Number of Subjects in Cross-sectional and Longitudinal Samples[a]

	Egypt	Kenya	Mexico
No. Households	312	292	320
No. Persons in Household, mean	7.5	7.28	10[b]
Target Subjects, Cross-sectional[a]			
Lead males	289	285	271
Lead females	290	286	284
Schoolers	123	222	195
Toddlers	157	133	149
Infants	130	14[illegible]	98
Target Subjects, Longitudinal[c]			
Lead males	153	214	155
Lead females	153	214	158
Pg/lact females/infants	62	93	69
Schoolers	42	129	109
Toddlers	88	91	55

[a] Total enrolled; number useful for analysis is less depending on variable of interest. See text.
[b] Mode.
[c] Longitudinal sample is defined by the following criteria: toddler, at least one food intake record prior to age 19.0 months and after age 29.0 months; schooler, at least one food intake record between the ages of 7.0 years and 8 years 1 month, and 10 months later; pregnancy/lactation, lead female with at least one food intake record prior to her infant's birthdate minus 5.0 months, and at least one food intake record after her infant's birthdate plus 5.0 months.

FINDINGS

The data analyses reported here are but a small beginning of a major task. Descriptive statistics are presented to provide a context in which analytical results are to be viewed. Simple bivariate regression and correlation analyses serve as indicators of possible associations between variables that warrant further investigation. Because many of the variables are intercorrelated, multiple regression analyses are usually required before major explanatory factors can be identified with confidence. Project reports, and to some extent, the present report have used multivariate techniques but much more work remains to be done.

No project carried out a complete dietary or nutrition survey in advance of selection of the sample study population (but notice was taken of social, economic and/or geographic features). As food intake was not a selection criterion, the existence within a project of a sufficient range of intakes for adequate testing of the hypotheses is not assured. Furthermore, the upper boundary of a narrow, depressed range of intake observed in one project might be in the lower range of intake in another population where food availability is not so constrained. Viewed in isolation the upper range of generally low intakes would be classified as "good" even though it may have been inadequate. Such misclassification would attenuate correlations that might be demonstrable if the spectrum included truly adequate intakes. Examination of relationships across projects can benefit from the existence of large differences that exist between them. These differences may shed light on the reasons why what is found within one project may not be found within another.

As time and funds were running out in the last year of the CRSP, the PIs elected to focus their attention on hypotheses involving toddlers and the mother-infant pair. The present report picks up these threads and extends the work to preliminary examination of other hypotheses, including an assessment of the pattern and determinants of childhood growth.

FOODS CONSUMED

The types of foods consumed in each of the country projects show several similarities as well a numerous differences. An example of foods reported by a mother and her toddler for a day is shown in Table 2.

In these sample data, the variety of items is least in Kenya and greatest in Egypt. The only source of animal protein in this Kenya diet is a small amount of milk, while meat is present in both the Egypt (chicken) and Mexico (beef) diets. Furthermore, both Egypt and Mexico sample diets contain eggs. The major energy source is a carbohydrate-rich food in all three areas: flat bread in Egypt, maize in Kenya and tortillas in Mexico.

ENERGY BALANCE

Energy Intakes.

In comparing data from the three country projects, the most striking observation is the lower energy intakes reported for all age groups in Kenya, whether expressed as absolute intake or intake per kg body weight (Table 3). There is a general similarity in mean intakes per kg body weight for the Egypt and Mexico children, but Egypt adult intakes are less than Mexico figures and close to Kenya when adjusted for body weight.

TABLE 2

Sample diets of a mother and toddler pair in each project
(ounces consumed in one day)

Food	Mother	Toddler
EGYPT (February, 1984)		
Tea (with sugar)	–	2
Fenugreek tea (with sugar)	5	–
Buffalo milk	2	2
Aiysh balady (whole wheat flat bread)	13	7
Cooked egg	3	3
Karate (cheese "puffs", commercial product)	–	.5
Cheese	2	1
Tomato (raw)	11	9
Orange (raw)	9	6
Firaak (chicken) with taro, tomato, water, onion, fat and garlic	23	19
KENYA (February, 1985)		
Tea with milk and sugar	25	15
Whole milk	–	.7
Fermented porridge made of maize meal, water and sugar	20	9
Gitwero made of potato, banana, water, oil and salt	–	10
Githeri made of maize, beans, water, fat and onions	38	–
MEXICO (JUNE, 1985)		
Coffee with sugar	8	–
Atole d'harina made of rice, flour, water and sugar	–	17
Tortillas	28	10
Huevo (egg) with tomato, onions, oil and salt	2	2
Calabacitas (squash) with onions and oil	3	2
Carne guisada made of beef, tomatoes, onions and salt	7	.3

The distribution of children's energy intakes is arrayed in Figures 3 and 4, compared with the average energy requirement per kg body weight as estimated by international bodies.[1] Intakes of Kenya toddlers are almost all below the average requirement value, whereas Mexico and Egypt intakes (excluding the extreme and possibly erroneous outliers) are more evenly distributed and, on average, approximate the estimated average requirement. Intake of Kenya schoolers is quite close to the estimated average requirement; in Mexico and Egypt, intakes of schoolers, particularly the girls, are above estimated average requirements.

For adults, a judgment must be made about activity level to derive an estimate of average requirement. The requirement estimates portrayed in Figure 5 reflect the international standard for "moderate activity".[2] As the adults did not change appreciably in body weight over the period of study,[3] if the reported energy intakes are correct, the observed intake is the same as the requirement, that is, enough energy was consumed to match the energy expended. On that basis, the activity of adults in Egypt would be classed as "light"; intake of women in Mexico suggests a "heavy" work pattern and that of men is just above "moderate"; intake of Kenya women and men was insufficient to support a "light" activity pattern and they would be rated as "sedentary". Examined in the light of observed characteristics of the three sites -- occupations, access to labor-reducing technology, climate -- the predicted activity patterns for Egypt and Mexico are within credible limits. The sedentary expenditure pattern predicted from the intake figures for Kenya does not, however, fit the expectation for an agricultural community lacking modern conveniences. Before accepting the intake figures as a true representation of requirement in any case, it is well to consider the evidence bearing on the reliability of both intake and expenditure factors in all three locations.

On the expenditure side of the energy balance equation, there is the postulate of "cost-free" metabolic adaptation mentioned earlier; this can be examined in Kenya and Mexico. It would be desirable also to have direct verification of activity patterns; some useful evidence on this point was obtained late in the Kenya study. Factors that might affect validity of the intake side are errors/biases in reported food intake, errors in food composition data and differences in digestibility/absorbability of the diet. Changes in body weight and/or composition would enter into the balance equation, but there is no evidence to indicate that there were net changes in these compartments in adults over the period of study (although there were temporary changes due to pregnancy, lactation and food scarcity).

Metabolic adaptation.

The RMR values reported for Kenya men, women and schoolers provide no evidence that they are metabolically adapted to low intake, that is, the RMR per unit of body weight accords reasonably well with expected values.[4] The measured RMRs in Mexico almost exactly matched predicted values.

---

[1] FAO/WHO/UNU, op. cit. Table 49. Requirements for children assume normative activity.

[2] Adult energy requirements are expressed as multiples of BMR and are, for activity patterns classed as "light", "moderate", and "heavy" respectively: for men, 1.55, 1.78 and 2.10; for women, 1.56, 1.64 and 1.82. Ibid Table 15.

[3] Kenya adults lost weight during the drought period but regained it afterward. A one-year time span is insufficient to detect the very gradual change in body weight that often occurs in mature adults.

[4] The measured RMR of Kenya men was about 24 kcal/kg; the FAO/WHO/UNU equation predicts a value of 27 kcal/kg. It is recognized that the equation tends to increase estimated RMR of smaller and lighter people. Observed RMR of Kenya women was closer, within about 3-5%, of predicted. The RMR method used in Kenya was shown to produce slightly lower values for men than an older, comparison method. See ME Final Report for details of RMR analyses.

Table 3

Energy and Nutrient Intakes (mean ± standard deviation)[a]

Group	Energy	Protein	Carbohydrate	Fat	Animal Protein
A. EGYPT PROJECT					
	kcal/d	g/d	g/d	g/d	g/d
Toddlers	1173±316	36.1±10.7	189±52	31.3±9.7	13.8±5.3
Schoolers	1798±407	56.5±14.5	296±67	44.4±12.0	19.0±7.1
Men	2710±403	87.9±14.0	439±69	69.3±16.5	29.7±11.2
Women	2201±318	70.2±11.0	359±57	55.7±11.0	22.6±7.0
	kcal/kg/d	g/kg/d	g/kg/d	g/kg/d	g/kg/d
Toddlers	108±31	3.3±1.0	17.3±5.1	2.9±0.9	1.26±0.48
Schoolers	81±22	2.5±0.8	13.3±3.6	2.0±0.6	0.86±0.35
Men	39±7	1.3±0.2	6.4±1.3	1.0±0.2	0.44±0.15
Women	35±8	1.1±0.3	5.8±1.4	0.9±0.2	0.35±0.11
B. KENYA PROJECT					
	kcal/d	g/d	g/d	g/d	g/d
Toddlers	844±184	23±5	166±37	13±4.7	3.2±2.5
Schoolers	1447±266	43±9	287±52	21±5.7	2.5±2.0
Men	1954±439	58±13	380±89	30±8.6	5.2±4.0
Women	1672±339	49±11	329±64	25±8.0	4.1±3.2
	kcal/kg/d	g/kg/d	g/kg/d	g/kg/d	g/kg/d
Toddlers	84±18	2.3±0.6	16.6±3.2	1.3±0.5	0.34±0.24
Schoolers	72±12	2.1±0.4	14.4±2.4	1.1±0.3	0.12±0.09
Men	36±8	1.1±0.3	7.0±2.7	0.6±0.2	0.09±0.07
Women	33±7	1.0±0.2	6.4±1.3	0.5±0.2	0.08±0.06
C. MEXICO PROJECT					
	kcal/d	g/d	g/d	g/d	g/d
Toddlers	1119±285	33.8±8.52	193.9±56.7	23.1±8.37	9.6±5.5
Schoolers	1828±462	54.1±13.4	36.0±89.2	29.5±10.2	10.2±6.5
Men	3070±747	84.3±20.6	496.9±130.9	41.2±15.2	14.9±10.3
Women	2572±643	73.1±17.9	455.1±119.4	38.1±13.9	12.5±8.6
	kcal/kg/d	g/kg/d	g/kg/d	g/kg/d	g/kg/d
Toddlers	102±32.8	3.10±0.96	17.63±6.25	2.08±0.84	0.87±0.48
Schoolers	86±21.2	2.55±0.65	15.81±4.14	1.37±0.45	0.47±0.29
Men	47±12.2	1.30±0.33	7.63±2.10	0.64±0.24	0.23±0.15
Women	44±13	1.26±0.36	7.83±2.36	0.65±0.25	0.21±0.14

[a] Data for the longitudinal sample excluding information from toddlers who are still breast fed, from Egypt project records with missing meals, and from Kenya project records with missing nutrient values. For Mexico, only data collected after January 1, 1985 are included. For each subject, the mean intake across all observations has been computed. For the expression of intakes per kg, all body weight data for the individual were averaged to yield a single estimate of the individual's weight. In toddlers and schoolers, neither the intakes nor the weights used in the calculations are age-adjusted.

Figure 3. Histogram of Distribution of Energy Intakes of Toddlers Compared with Reference Requirements for Normative Activity, Kcal/kg/d

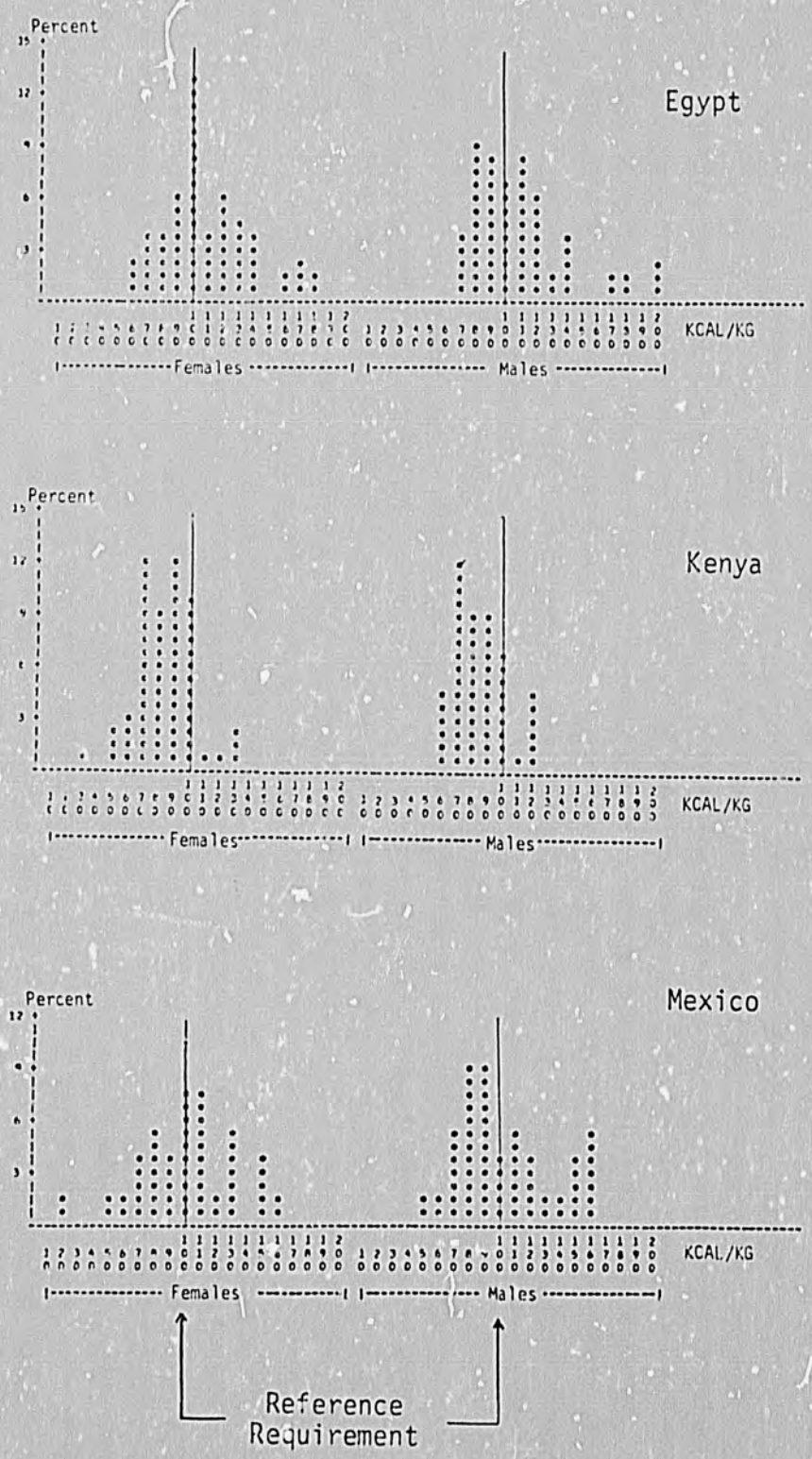


Figure 4. Histogram of Distribution of Energy Intakes of Schoolers Compared with Reference Requirements for Normative Activity, Kcal/kg/d

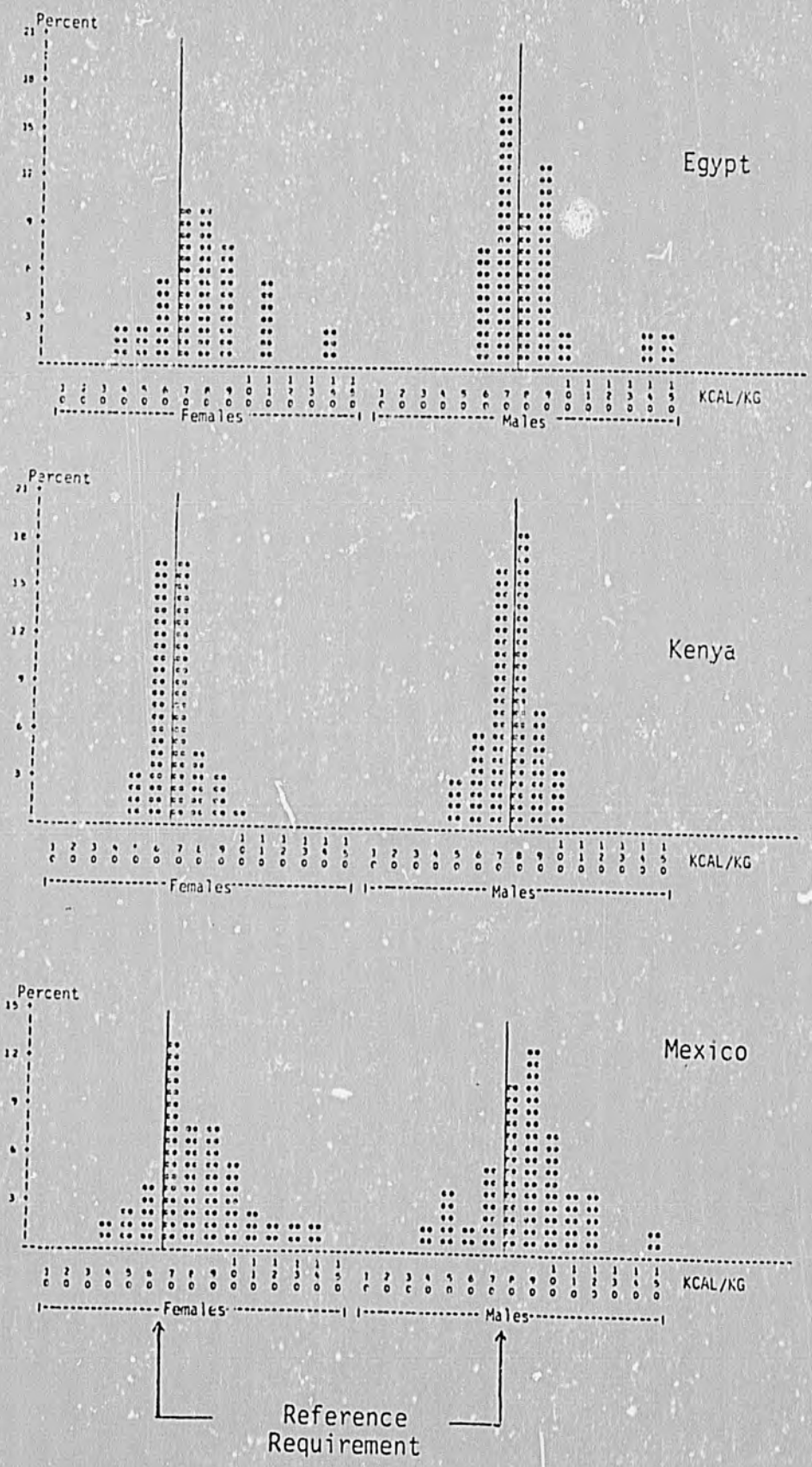
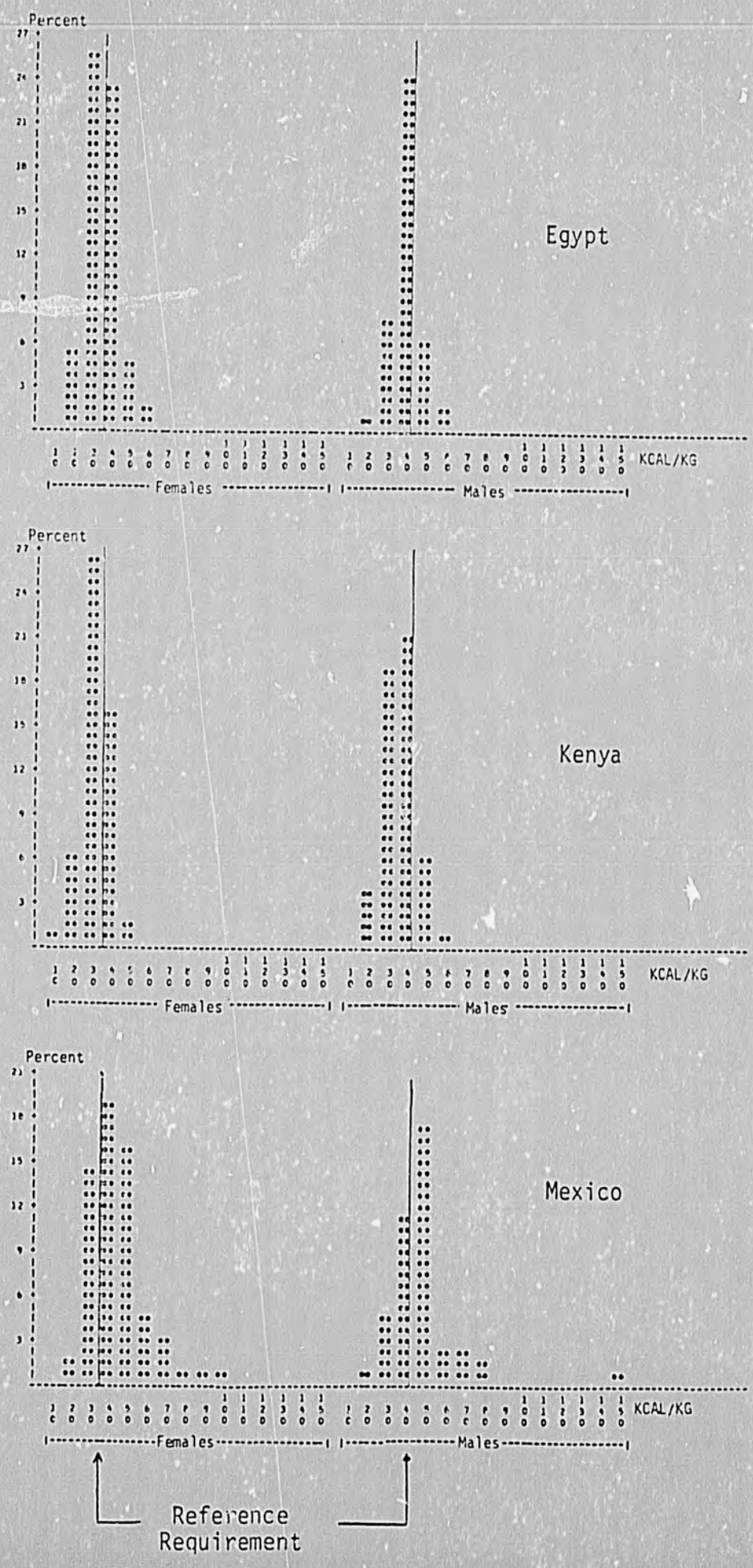


Figure 5. Histogram of Distribution of Energy Intakes of Adults Compared with Reference Requirement for Moderate Activity, Kcal/kg/d



A "natural" event in Kenya, the drought, resulted in restricted food intake and provides an opportunity to look for forced adaptation. If the processes of energy metabolism are capable of homeostatic responses to maintain energy balance in the face of such pressures, one might expect to find an effect of restricted intake on measured RMR -- a fall during the period of food shortage and a rise during the recovery period. This hypothesis was examined through a series of paired analyses (comparing RMR estimates for the same subject in two phases of the food shortage/recovery period). Comparing body weights before and late into the period of food scarcity, men had lost 1.7 ± 4.3 kg and women, 2.3 ± 4.0 kg; six months after the period of critical shortage, men's weight had increased by 2.5 ± 4.5 kg and women's by 2.2 ± 4.7 kg. Schoolers showed a diminished rate of weight gain during the shortage but did not lose weight on average. Food intake of adults fell by about 400-500 kcal/day during the shortage period and that of schoolers by 200-300 kcal/d, despite a food relief program. Small differences were observed in the total RMR of men and women, but this was explained by the changes in body weight. As shown in Figure 6 for adult males, RMR per kg body weight was the same in all periods.

Another time at which metabolic adaptation might be seen is during pregnancy and lactation, when the mother must meet extra energy demands. Data for women in both Mexico and Kenya are presented in Figure 7. RMR per kg body weight was the same in the two locations even though energy intakes differed by about 1000 calories per day. The expected small increase in RMR was seen during pregnancy in both locations, and in both, the average value was 23-24 kcal per kg irrespective of reproductive status; that is, RMR in pregnancy increased in proportion to the increase in body weight.

A third place in which physiologic adaptation to reduced intake might occur is in the energy cost of performing work tasks. The Kenya project measured the energy expended during household tasks (washing, cooking, chopping wood) and agricultural tasks (weeding, picking coffee, harvesting beans, etc).[1] The values reported tally nicely with values reported by others for similar activities. For example, the energy expenditure for both men and women sitting at rest was 1.2 times the RMR, weeding was 3.2-3.4 times RMR, and threshing, 5.9-6.4 times RMR, factors virtually identical with those tabulated by the FAO/WHO/UNU.[2] Thus, there is no indication that this population, chronically living on a low plane of intake, is any more efficient -- or less -- in performing work than are others.

These observations have important relevance for nutrition policy. They strongly suggest that changes in food intake are not absorbed by compensatory changes in metabolism and hence must be associated with other adaptive mechanisms -- change in body tissue mass, as demonstrated in the food-scarcity period, and/or change in activity-demanding behaviors as originally hypothesized in the design of the CRSP.

Activity pattern.

There is a strong implication, if food intake figures are correct, that what many Kenya adults were able to do was constrained by food availability. The Kenya project deferred study of how adults spend their time until the second year of the study (3/85-2/86). Thus, there are no data on activity for the period of food shortage. The method used to study time allocation in Kenya -- intermittent observation of activities during the daylight hours -- allows construction of an "average" activity pattern across one full agricultural cycle[3].

---

[1]See the Kenya Project Final Report, Table 17.3. Measurements were made on eight men and seven women.

[2]op cit, pp. 186-191.

[3]See the Kenya Final Report Table 15.1 for for times; calculation of energy equivalent was done by the present authors.

Figure 6. Comparison of Energy Intakes and Resting Metabolic Rates for Adult Males Before, During and After Food Shortage in Kenya

(paired data)

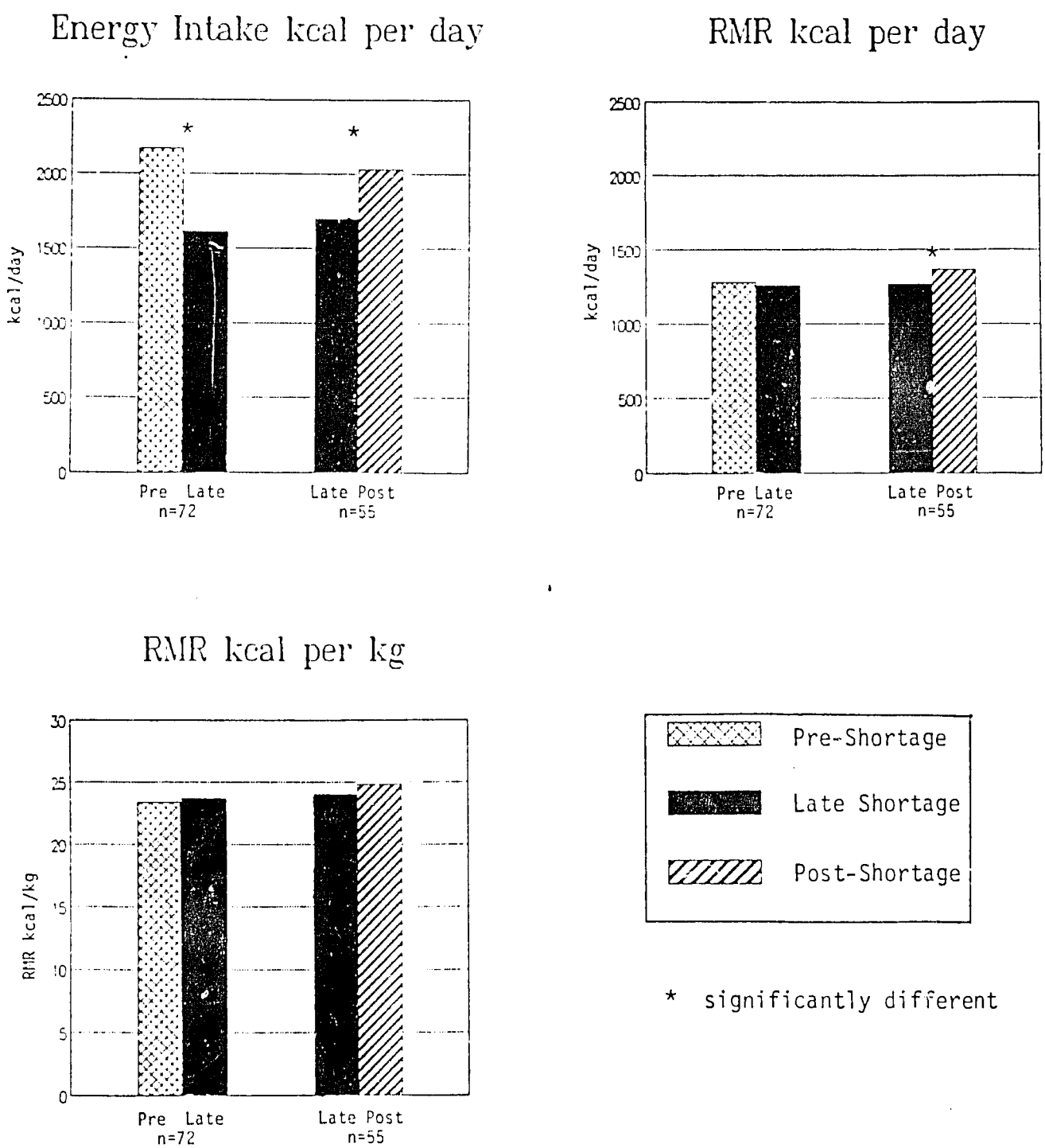
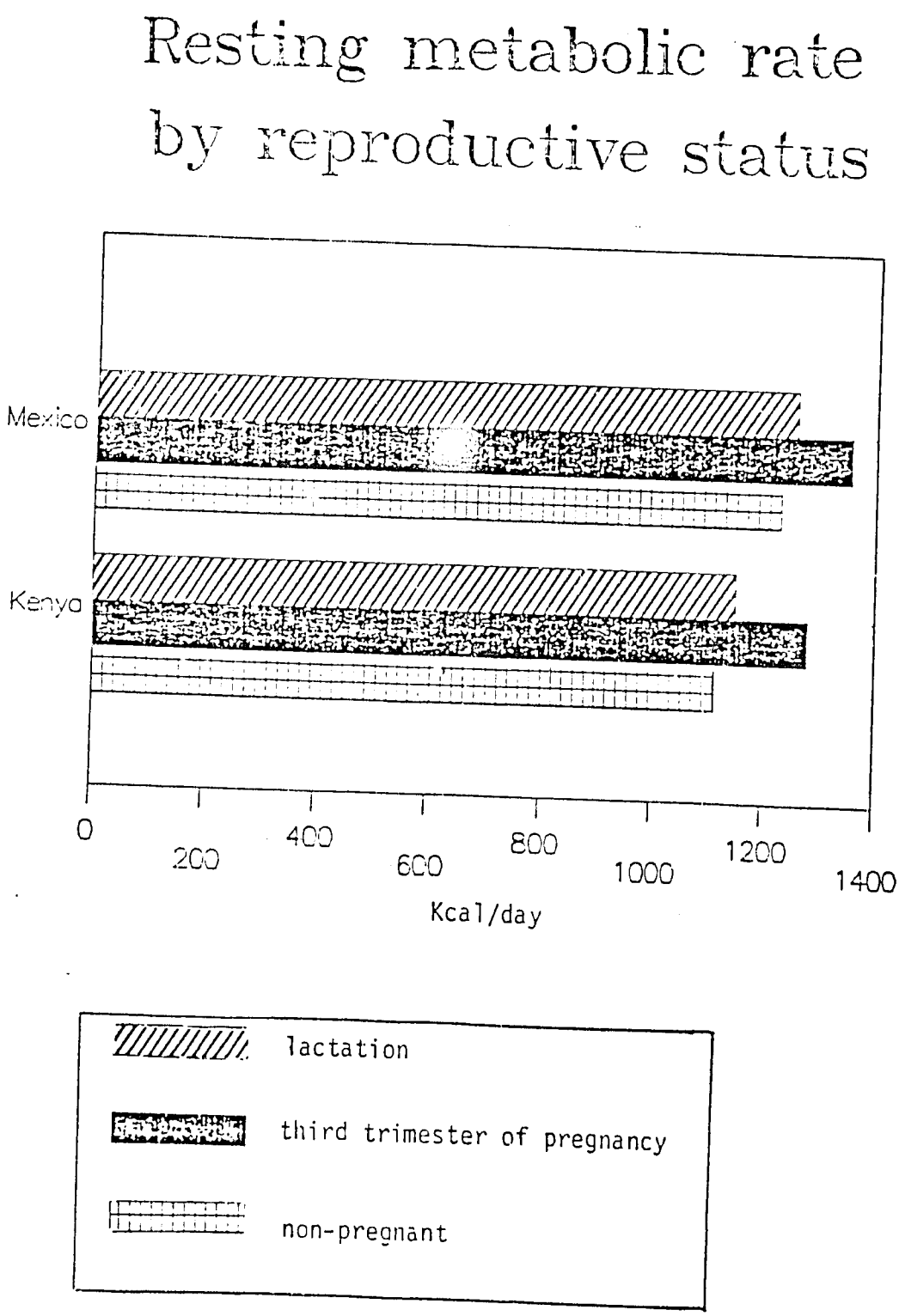


Figure 7. Resting Metabolic Rate for Adult Women by Reproductive Status in Mexico and Kenya



It is possible to assign energy values to these activity-times using figures suggested by FAO/WHO/UNU,[1] recognizing that many assumptions are required for even rough calculation of energy equivalency. Counting the unobserved times of day as rest, the typical Embu man's daily energy expenditure during a normal year was about 1.77 times RMR, and that of women was 1.55 times RMR. These levels are classed as "moderately active". Activity patterns could have been, and probably were, less energy-intensive during the drought; the need for heavy planting, tilling and harvesting work was reduced and there were few other opportunities for employment that would have demanded physical work. Assuming a maintenance activity level during the drought period (1.4 x RMR for six months) and the factors calculated above for the remainder of the study, the average expenditure pattern would be 1.51 x RMR for women and 1.68 x RMR for men. These figures are 10% above observed intake (36 vs. 33 kcal per kg for women and 40 vs. 36 kcal per kg for men).

Pregnant women reduce their activity levels, if they can, to compensate for the added burden of reproduction. The Kenya project reported[2] that pregnant women increased "inactive" time by 70 minutes a day (a 140% increase) and decreased time spent in food preparation and care of self and others by a like amount. Depending on assumptions about the energy cost of work foregone, this change would net about 100 kcal per day or 2 kcal per kg. This amount of savings would not be enough to close the gap between "sedentary' and "moderate activity" categories, but the nature of the accommodation is illuminating. The activities which were decreased under conditions of uncompensated energy demand are those likely to impact adversely on the quality of nurturance and standards of hygiene. It is, then, perhaps not surprising that the sanitation score of Kenya households was found to be significantly positively correlated with the lead female's energy intake, as well as with some other household characteristics, and to be lower where the woman was, herself, more often ill.

Women in the Mexico study appear to live at the upper range of energy expenditure patterns, based on their observed intake. A pilot study of women's activities sheds some light on factors that might explain this heavy work demand. Feeding the family required not only cooking, a moderate activity, but preparation steps that are energy-intensive, such as carrying heavy buckets of pre-soaked corn to the mill for grinding and back home again (activity that may cost six times the RMR) several times each week. Maintaining cleanliness is also energetic in the absence of household appliances; for example, the women spent nearly eight hours a week washing clothes (activity three to four times RMR). In addition to these and other household tasks and caring for children, the women also cared for animals and participated in agricultural work. There is, of course, variation within a population in the kinds of work women do and in facilities available to ease the burden; the Mexico project found a strong positive correlation between energy intake and the energy cost of recalled 24-hour activity in the sample population. In the longitudinal study, activity of mothers and toddlers was observed for 110 minutes over a period of 10 hours. There was a negative correlation between maternal energy intake and the amount of time she was observed "doing nothing", but in toddlers, observed activity was not associated with energy intake. What the findings in the Mexico population seem to indicate is that the amount of energy consumed was determined by energy demand. (This contrasts to the situation in Kenya where the activity level was likely to have been adaptively lowered in the face of low energy supply and intake.) Although some exceptions may be found within the sample, at the time of the study people in the Solis Valley appeared to have enough food available to sustain their necessary and expected work patterns. Under these conditions, variation in the functions of interest, the outcome variables, are unlikely to be related to energy intake per se. A similar conclusion can be inferred for the Egypt population, where intake was sufficient to support a light level of activity.

---

[1] op. cit., p. 76

[2] See Kenya Final Report Table 23.15.

Errors in energy intake.

Measurement of food intake is the most difficult and time-consuming procedure in any large nutrition survey, and none has ever produced data of the quality and scope to match this CRSP. Still, the methodology is subject to substantial error and biasing of results. The lead female was the principal respondent, and data for this target group would be expected to be most reliable, depending on the women's ability to observe, remember and report their own food intakes. The record of supplementary food given to infants might be equally reliable, but to the extent that toddlers are mobile and unobserved, food consumption and food wastage both may be unrecorded. Many toddlers were, as well, partially breast fed up to, and a few beyond, two years of age. Measurement of breast milk intake was not feasible and cannot be estimated reliably. Schoolers and lead males might have reservations about reporting food eaten away from home if, for example, the piece of fruit came from a neighbor's tree or a purchased street food was an unwarranted expenditure of scarce funds. If there is a social stigma associated with consumption as, for instance, with alcoholic beverages, intake may not be acknowledged. Food consumption is often different on holidays and days of religious observance than during the rest of the time; two of the three projects have few or no records of those days. These factors all make for underestimation of food intake.

The Egypt project gave special attention to food consumption during the month of Ramadan, a period of fasting, and to feasting on the days that follow. Intake on Saturday, the day of religious observance, was fully represented in the data set. During Ramadan, adults and older children abstain from food and water during the daylight hours, eating only at night and before dawn. The data indicate that energy intake was not noticeably changed by the shift in eating times.[1] Energy intakes recorded on the two days after Ramadan were higher than intakes in the months before and after Ramadan by about 700 kcal/d for adults and schoolers and over 500 kcal/d for toddlers. If these data are indicative of celebratory feasting in general and if there were six such feasting days a year, failure to account for them would amount to a loss of 3000-4000 kcals/year, or about 10 kcal/d, a negligible amount in terms of energy. (As foods eaten on special occasions are different and often of nutritionally superior value, other components may be of greater biological significance.) Saturday/Sunday menus also may differ from other days. Egypt project reported energy intake of lead females and toddlers to be 10% higher on Saturday than on other days of the week.

Underreporting of alcohol is a known problem in Kenya and Mexico. In Mexico, consumption of the locally brewed pulque (a beer-like beverage, about 2% alcohol, 43 kcal per 100g) is accepted as the norm for adults, including pregnant and lactating women and older children The custom of fermenting agave juice may have had survival value in times of food scarcity because this processing allows consumption of an otherwise nonutilizable substance available in the environment. Pulque contributes 12% of dietary energy for men and 6% for women as reported in this study. Usual intakes by men were 500 ml to one liter (500 to 1000 g) a day with some reporting three to five liters per day. The Mexico project reports that 80% of men and 12% of women acknowledge drinking to the point of inebriation with varying frequency. Heavy drinking tends to occur on Saturday and sometimes Sunday, times at which consumption data were not collected. So, while pulque appears regularly in food intake records, consumption may still be somewhat higher than the reported mean figures. On days of high pulque consumption, the beverage may or may not have displaced other caloric foods, with a net effect of either increasing or decreasing, or having no effect on, total energy consumption for the day. When adults drink to inebriation, the food intake and care of children may suffer, but the project has not examined this point.

Records of alcohol consumption seem to be less complete in Kenya. Alcohol appears in the food intake records of only one woman and 39 men. The woman reported drinking 240 g of beer on

---

[1]Mean intake of lead females was 2220 ± 699 kcal/d in the month before, 2189 ± 775 kcal/d in the month after and 2089 ± 651 kcal/d during Ramadan. Comparable figures are, for schoolers, 1856 ± 704, 1773 ± 689 and 1813 ± 705 kcal/d; and for toddlers (not required to fast) 1115 ±514, 1059 ± 517 and 1029 ± 468 kcal/d. None of the Ramadan figures is significantly different from the control months.

two dates; average intake of the men was 2033 g, ranging from a low of 338 g to a prodigious 8750 g. The energy value of the variety of local and commercial beers consumed is about 50 kcal per 100 g, yielding over 1000 kcal per day as the average figure for those men whose food records acknowledge drinking. The Kenya project conducted an inquiry separately from the food intake interviews to estimate the validity of the data reported on the food forms. According to the food records, only 17% of men drank beer, but the questionnaire revealed that 53% of men drank two pints (one liter) or more each day; the male average figure from the survey was 1227g, equal to about 600 kcal. Most women did not drink beer at all; the average consumption was 14 g per day. If the alcohol calories are additive to the diet as recorded, the energy intakes of many men, but not women, are substantially underreported. The impact of adding 600 kcal to the diet of 36% of the men (the 53% who acknowledged drinking less the 17% who reported it) would be to raise the group mean intake by about 200 kcal per day and nearly 4 kcal per kg, enough to raise the estimate of energy expenditure of men to the "light" activity category. No comparable source of error can be identified in the case of women.

Other features of food intake methodology can result in falsely high reports of intake. If the interviewer is different from the population being studied (more highly educated, wealthier, etc.), respondents may improve the family diet on scheduled days of interview, producing true but unrepresentative records. In the Egypt project, it was possible to document that some interviewers recorded systematically higher intakes than did others. This bias has been taken into account in analyses reported by that project. It has not been possible to determine whether analogous effects existed in other projects.[1]

Intake records also may be biased if days of illness are not proportionately represented in the data set purporting to represent "usual" intake. The Kenya project recorded food intake on scheduled days irrespective of illness and has examined intake of toddlers on days well and ill. Healthy toddlers consumed 861 $\pm$ 465 kcal per day, those with fever 719 $\pm$ 440 kcal and with gastrointestinal complaints 699 $\pm$ 407 kcal, significantly less.[2] The Egypt project has looked for bias due to illness and reports that illness days are correctly represented on the average intake figures (but not necessarily in individual cases). There are insufficient numbers of illness days that coincide with food intake adequately to test the Mexico data set for this bias, but the situation appears to be the same as in Egypt. No other target category than toddlers presents sufficient numbers and types of illnesses for statistical testing, but it is reported that food intake interviews were rescheduled in Mexico and Egypt if the lead female was ill, an infrequent but significant occurrence.

Digestibility.

Questions were raised by the projects concerning the digestibility and, hence, true energy yield of the diets eaten in the three countries. The diets contain large amounts of whole grain cereals, legumes and other plant foods high in fiber, which are less digestible than foods of animal origin and refined cereal products. The thought was that energy values calculated from food tables might be higher than is actually the case. The energy values of foods given in the tables of food composition used worldwide (and in the CRSP) are based on the human digestibility and energy experiments conducted by W.O. Atwater at the Connecticut Agriculture Experiment Station in the early 1900's.[3] Much more is now known about the components and effects of dietary fiber and some reconsideration is in order.

---

[1]The 1985 methodology change in Mexico involved the use of more highly trained interviewers than in 1984; reported food intake increased by about 300-400 kcal per day for adults and schoolers and by 160 kcal per day for toddlers after the interviewer change. The project's validation study confirmed the higher figures.

[2] See Neumann, C. et al. FASEB J. 2:A1194, 1988.

[3]USDA Handbook #74, 1955. Atwater reported figures to be applied to individual foods and food groups; these are called Specific Energy Values and are used in most tables of food composition. The figures of 4 kcal per gram of carbohydrate and protein and 9 kcal per gram of fat are averages pertaining to typical US diets

Human studies require strict control of intake and output not possible under usual field conditions. The Egypt Nutrition Institute did, however, undertake a study of toddlers using the village clinic as a field laboratory. A personal communication from Dr. Wafaa Moussa reports digestible energy to have ranged from 82 to 92% for the six toddlers studied, which coincides well with the values developed by Atwater. Since completion of the CRSP, a trial of a prototype rural Mexican diet has been carried out in Mexico by Dr. J.L. Rosado.[1] His figure for metabolizable energy, 90%, also coincides with figures calculated using Atwater's digestibility factors and Specific Energy Values. The Mexican test diet did not include pulque, and some doubt remains as to digestibility of the carbohydrate present (accounting for about half of the pulque calories). It appears, however, that the dietary energy values as calculated for Egypt and Mexico are reasonably reliable, or at least as reliable as knowledge about the composition of foods consumed permits. The Kenya diet, being lowest in animal products, may be slightly less digestible than the Mexican diet, but the difference is probably within the error term of the method.

Food Composition

Some amount of error due to incorrect food composition is to be expected since foods analyzed to obtain composition data are virtually never the same as foods in a specific diet. Other problems can occur due to obsolete analytic methodologies, improper collection of samples, or data entry errors. The CRSP projects endeavored to minimize these problems by extensive computer-aided checking of the food composition tables, careful estimation procedures for missing (non-analyzed) nutrient values, and, in two projects, comparison of calculated and analyzed nutrient values. Egypt project analyzed the nutrients in seven composite diets (for different target individuals) and found that calculated energy values were 8% greater than analyzed on average, with ranges from -12 to +31% (one diet with obviously incorrect analytic data was excluded). Analytic values for twelve typical dishes were compared to calculated values by the Kenya project. The average difference was less than 3%, with a range of -16 to +22%. Thus, it appears that errors in mean energy values of multiple diets are likely to be small, but energy estimates for individual diets may on occasion have substantially larger errors.

Conclusions

After considering the many factors that could affect the validity of the energy intake and expenditure figures and their implications, the following conclusions seem warranted:

-- Food energy intake was lower in Kenya than in Egypt or Mexico;

-- Body metabolism was not lowered in response to chronic food shortage, thus there is no evidence for a cost-free adaptation to constrained food energy supply;

-- Reported food energy intake was not sufficient to support the moderate activity level observed in Kenyan adults during a period of normal food availability, but activity was likely to have been less during the drought period when adults lost weight; underreporting of alcoholic beverages may account for much of the discrepancy between intake and expenditure of men but not women;

---

[1]See Rosado, J.L. Bioavailability of Nutrients from Rural and Urban Mexican Diets. Ph.D. dissertation. University of Connecticut. 1988.

-- Reported food energy intake in Egypt was consistent with an assumption of light activity, hence, if there is an error in intake, it is likely to be underreporting;

-- Reported food energy intake in Mexico is consistent with a moderate-to-heavy activity pattern; if there is an error in food energy intake, it is likely to be overreporting;

-- Dietary energy appears to be a limitation in Kenya but not in Egypt or Mexico.

NUTRIENT CONSIDERATIONS

The second striking feature of the food intake patterns is the difference in fat and protein intakes across projects (Tables 2 and 3). Sites in different geographic areas were selected in anticipation of finding differences in the nature of the diets consumed, recognizing that this variation might be very important in interpreting the relationships between total food (energy) intake and outcome functions. The data in Table 3 confirm that indeed the macronutrient composition of the diets did differ among sites.

In all three countries, protein supplied about 12% of the dietary energy; the ratio was slightly higher in Egypt (13% of energy), and slightly lower (11%) in Mexico adults only due to the inclusion of pulque in the diet. The intake of protein, and many other nutrients, covaries with energy intake (correlation coefficients[1] are .85-.86). Broadly speaking, the lower the energy intake, the lower the total protein intake. Biologically, the need for energy has priority over the use of protein for its essential nutrient functions, so the effects of low energy intake and low protein intake are confounded. In the case of Kenya, it is to be expected that relationships found between energy intake and various outcomes will also be seen with protein. Because energy intake is unlikely to be limiting for the majority of people studied in Egypt and Mexico, associations between either energy or total protein and outcomes are unlikely as well.

Foods rich in protein also tend to be good sources of many other nutrients (B vitamins and minerals). The amount of iron present in these diets correlates with both energy (.74-.78) and protein (.58-.77). Iron is not equally absorbable from plant and animal sources. The factors that affect iron absorption are the presence in plant foods of inhibitors (fiber and certain other components) and facilitators (vitamin C). Iron in the form of hemoglobin (a blood protein present in meat) is much more absorbable than other forms, so diets higher in animal protein should be more reliable sources of iron. However, there is no evidence that iron status of the Egypt population whose animal protein intake was largest, was superior to that of Mexico or Kenya (Table 4).

Very few adult males had unacceptably low levels of blood hemoglobin or hematocrit (measures of functional iron adequacy)[2] or serum ferritin (an indicator of iron storage). Iron status was poorest in toddlers in all three locations but better in Mexico than in the other sites. About half of the toddlers had unacceptably low hemoglobin levels, and one-third to one-half were low in ferritin. Large numbers of pregnant women had unacceptable levels of hemoglobin (49% in Kenya, 28% in Egypt). In Mexico, the iron status of women during lactation was better than during pregnancy. In Egypt, iron status was poorer after six months of lactation, and poorer in women who had had several previous pregnancies than in those pregnant for the first time, indicating that reserves of iron were not being restored between pregnancies.

---

[1]A correlation coefficient provides a single number, ranging between -1 and +1, which summarizes the linear relationship between two variables. If the correlation coefficient is close to zero, we can assume there is little or no linear relationship between the two variables. If it approaches +1 there is a strong positive relationship, and if it approaches -1 there is a strong negative relationship.

[2]Values for hemoglobin and hematocrit are normally higher in populations living at high altitude as in Kenya and Mexico. See footnote to Table 4.

TABLE 4

Iron Intakes and Indicators of Iron Nutritional Status in Egypt, Kenya and Mexico

Parameter[a]	Toddlers	Schoolers	Lead Males	Lead Females
		Egypt		
Iron Intake	7.4 ± 5.6	9 ± 9.0	17.8 ± 6.6	16.2 ± 9.2
Hemoglobin	10.6 ± 1.3	12.7 ± 1.0	14.9 ± 2.2	12.8 ± 6.2
Hematocrit	34.2 ± 3.3	37.4 ± 2.3	43.8 ± 5.7	36.9 ± 3.8
Ferritin	18 ± 15	34 ± 26	54 ± 43	29 ± 26
		Kenya		
Iron Intake	6.3 ± 4.6	12.8 ± 7.3	17.9 ± 10.9	15.4 ± 9.3
Hemoglobin	10.7 ± 1.7	12.1 ± 1.5	14.9 ± 1.8	12.2 ± 1.8
Hematocrit	33.5 ± 3.6	36.2 ± 3.4	43.0 ± 4.1	36.8 ± 4.6
Ferritin	19 ± 30	36 ± 39	76 ± 87	23 ± 35
		Mexico		
Iron Intake	11 ± 6	21 ± 6	36 ± 17	28 ± 13
Hemoglobin	11.5 ± 1.3	12.6 ± 1.0	15.4 ± 1.1	13.0 ± 1.2
Hematocrit	36.4 ± 4.6	38.5 ± 4.2	47.4 ± 4.2	40.4 ± 4.3
Ferritin	26 ± 52	24 ± 15	131 ± 111	31 ± 34

[a] Mean ± standard deviation: iron intake, mg/d; hemoglobin, g/dl; hematocrit, or packed red cell volume, %; and serum ferritin, mg/dl. The standard for ferritin is > 10 mg/dl for all age groups. Standards for hemoglobin for the four age/sex groups are: sea level, 11.0, 12.0, 13.0 and 12.0 g/dl; altitude, 0.5 g/dl higher. Hematocrit standards are: sea level, 33.5, 36.0, 33.0 and 33.0%; altitude, 1.5% higher.

In Mexico, a large proportion of men (27%) and a small number of other target groups (2-9%) had abnormally large red blood cells, rather than the small cells usually observed with iron-deficiency anemia. Enlarged cells usually indicate deficiency of the B vitamin folacin and/or vitamin B-12. Consumption of pulque was found to be a contributing factor, i.e. pulque consumption was positively correlated with red blood cell size. As alcohol is known to impair absorption and utilization of folacin, this seemed a likely explanation for the blood cell finding in male adults.

After the CRSP ended, the Mexico project analyzed some reserved samples of toddler blood for folacin and vitamin B-12; none were low in folacin, but 42% were low in vitamin B-12.[1] Vitamin B-12 is not present in plant foods, so an inverse correlation with animal food intake would be expected, but the project has not yet reported on dietary associations. A preliminary evaluation of diets of toddlers with hemoglobin levels above or below a low standard (10.5 g/dl in Kenya and Mexico, 10 g/dl in Egypt) showed no difference in any dietary variables of record (energy, protein, animal protein, fat, iron).

In Kenya, clinical signs suggestive of B-vitamin deficiency (abnormalities of tongue and lips) were seen in about 10-15% of schoolers, 1-2% of toddlers, 6-7% of women and 1-2% of men, with slightly higher frequency in adults during the drought. There was no clinical evidence of vitamin A deficiency nor any rickets. About 20% of women, 5% of schoolers and 1-2% of men had some enlargement of the thyroid (possibly but not certainly due to iodine deficiency) but no goiters were seen. Mottling of teeth, due to excess fluoride, was found in a few toddlers, 10% of schoolers, and 2-5% of adults. Overall, schoolers appeared to be at higher risk of nutrient deficiency than other age groups.

The Egypt project has identified a different essential nutrient problem, vitamin B-6. That project undertook to examine the nutrient composition of breast milk in comparison to samples from American women.[2] Breast milk is a reliable indicator of maternal nutrition status with respect to many essential nutrients, and the nutritional status of infants is dependent on its quality. Values for breast milk calcium, magnesium and zinc were not different from US samples except that calcium and magnesium contents were somewhat lower in Egyptian samples at the sixth month of lactation. Average vitamin B-6 levels were, however, 28% lower in Egypt than expected and indicate that the diet of some women is low in this nutrient. Breast milk vitamin B-6 content was used as a proxy for maternal status during pregnancy and lactation to examine relationships of vitamin B-6 with birth weight of infants, and with the Brazelton behavior score at 1-7 days of age. Low vitamin B-6 status had demonstrably adverse effects on both measures.

Why some individuals and not others have low iron and/or B-vitamin status is not now known. One explanation is surely to be found in unequal distribution of specific foods among consumers. Hence, the examination of food intake patterns across projects is an important next step to take in understanding the role food plays in functional outcomes. The kinds and quality of food available in a household reflect the family's ability to purchase or produce food and the menu decision-maker's knowledge of what constitutes a good diet. The biological mechanism by which economic status and parental education affect such measures as growth and mental capacity (as they are known to do) may well be chiefly through food.

Fat contributed a relatively small proportion of dietary energy in all three countries, 14% in Kenya, 19% of non alcohol calories in Mexico and 23% in Egypt (compare with the over 40% reported for the US diet). Fat, and other calorically concentrated foods, are of special importance in the diet of young children who oftentimes are unable to consume enough of bulky, watery foods to meet their energy needs before exceeding their appetite or volume capacity.

---

[1]Reported at the meeting of the Federation of Societies for Experimental Biology, Las Vegas, May, 1988, but not included in the published abstract: Black, A. K. et al. FASEB J.2:A 1204, 1988.

[2]See: The Egypt Final Report, pp. 290-292; Karra et al., Am J. Clin. Nutr. 44:330-5, 1986 and ibid 47:642-8, 1988; and McCullough et al. FASEB J 2:A437, 1988.

In the CRSP data sets, fat intake covaries with energy intake (.62-.63 in Kenya and Mexico, .80 in Egypt) but not as strongly as does protein intake (.85-.86). Fat intake also is correlated with intakes of total and animal protein (.57-.65), which are correlated with each other (.54-.75) as well. There is substantial variation in the percentages of dietary energy derived from protein, fat and animal products. In analyses, different questions can be asked by using these ratios in addition to or instead of absolute intakes. That is, it is possible to differentiate between the general makeup of the diet, a qualitative factor, and the quantitative factor of amount consumed.

Variability

The statistical power to detect associations between outcomes and one or another dietary factor depends on the relationship between the amount of variance within an individual's intake pattern and the amount of variance between individuals in the population. There was a notion, now discredited, that because the menus of poor people are less varied than those of the affluent, variability in their nutrient intake is less. Still, evidence available in the literature at the inception of the CRSP suggested that variability within individuals would be much less than proved to be the case. Variance was, in all cases, higher within than between individuals in the same age/sex category.[1] Variance both within and between persons was lowest for energy and almost equally low for total protein as would be expected from the strong relationship between these factors. The most variable component was animal protein intake. Among the three countries, variance within individuals was highest in Kenya and lowest in Mexico. The ratio of variances within and between individuals, the indicator of statistical power, was best in Mexico and poorest in Kenya. Only the variance ratio for fat intake in Kenya approached the ratio observed for all dietary factors in Mexico. The limitation in the size of the food intake data set in Mexico (due to the methodology change) is an offsetting factor that diminishes the advantage in statistical power of the superior variance ratios.

A very serious implication of these observations is the need to guard against the false negative interpretation of analyses. That is, if a relationship is not seen, it may be because it does not exist. It may also be because the attenuation due to variance is so great that it is not detected in conventional analyses.

The fact that variance ratios, and hence degrees of attenuation of relationships, vary between nutrient factors within projects and within nutrients between projects has clear implications. If, within a project, the real biological relationships between several nutrients and an outcome variable were comparable, the observed relationships would differ because of different degrees of attenuation. Analogously, between projects, different nutrients may appear as significant predictors of outcomes as a result of differences in variance ratios as well as because of true differences in the biological relationships. Examining the variance ratios alone begs the question of why the variance ratios differ, a most interesting subject that remains to be explored in depth.

BODY SIZE

Achieved size

There are both remarkable similarities and differences in body weight and height in the three populations (Table 5). Of these two measures, variability within a project is much less for height than for weight. Across projects, variability in both height and weight is greatest among Egypt school boys and adult women. In all projects, toddler weights are the least variable of the age

[1] See Appendix B.

groups. Among adults, the Kenya population appears to be the most homogeneous (i.e., least variable). Comparing data across projects, body weights are quite similar through the toddler age group in Kenya and Mexico. Mexico schoolers were taller and a little heavier than Kenya schoolers; by adulthood, Kenya and Mexico populations had achieved the same height, but Mexico adults were much heavier. Egypt infants began life somewhat heavier than the others but lagged at six months of age; as toddlers, their weights matched and as schoolers were above the other two projects; Egypt adult heights were the same as in Kenya and Mexico but their weights were much heavier.

Toddler weight gain

Weight gain in toddlers from age 18 months through 30 months was found to be linear for most children, although a substantial subgroup (approximately 16% in Egypt, 12% in Kenya, and 3% in Mexico) exhibited non-linear growth over this year.[1] An examination of morbidity rates for the Egypt toddlers did not show increased illness days or episodes in children with non-linear growth, implying other causes of occasional uneven gain (or loss). Egypt children gained weight faster during this year (.22 kg/month) than Mexico or Kenya children (.18 and .17 kg/month, respectively).

Comparison to reference population

Another way to view body size is in relation to a reference population where few persons are limited by environmental factors in reaching their genetic potential height and appropriate weight for height. The standards now widely used for this purpose are those prepared from studies of US children.[2] On a growth chart, the expected weights (or heights) at different ages are shown as lines. One line indicates the mean or 50th centile weight (or height) of the reference population. Sizes of 50% of the population are above and below this line. Other lines show weight (or heights) one, two or three standard deviations above and below the mean, or centiles of the distribution of weights or heights in the reference population. Thus, for example, when an observed weight falls two standard deviations below the mean of the reference population, it would be expected that about 2.3% of children in the reference population have lower weights. The observed weight could be described as approximating the second centile or as being two standard deviations below the mean. A child growing normally is expected to track along the same line, with variations up and down reflecting the irregularities of growth rate. If achieved size is expressed in either centiles or standard deviation units, normal growth would imply no change in the score. Use of either of these scores presents an approach to examining observed data for expected changes in weight or height with age. The scores also carry a built-in adjustment for differences in weight or height expected across sexes in children allowing sexes to be pooled for analytical purposes. The standard deviation score has been adopted in the present report where the common name "Z score" is used.[3]

---

[1] See Appendix C for several sample graphs showing toddler growth in the Egypt project.

[2] These are commonly known as the CDC or NCHS standards. See Dibley, M.J., et al. Am J Clin Nutr. 46: 736-748; 749-762, 1987.

[3]

$$\text{Z score} = \frac{\text{Observed weight - Reference Mean Weight}}{\text{Standard Deviation of Weight in Reference Population}}$$

A Z score of -1 represents a measurement that is 1 standard deviation below the mean or which lies on the 16th centile of the distribution of weights in the reference (US) population of children of the same age and sex; a Z score of -2 is slightly below the third centile.

TABLE 5

Body Weight and Stature[a] (mean ± SD)

Project/Group	Males Weight,kg	Males Stature,cm[b]	Females Weight,kg	Females Stature,cm[b]
EGYPT				
Birth	3.32 ± 4.9(63)[c]		3.13 ± 0.45(47)	
Infants, 6 mo.	6.8 ± 1.1(44)	65.5 ± 3.7(44)	6.4 ± 1.1 (35)	64.5 ± 1.7(35)
Toddlers, 24 mo.	11.5 ± 1.6(31)	80.8 ± 3.6(30)	10.8 ± 1.1(32)	79.3 ± 2.9(30)
Schoolers, 7 yr.	23.7 ± 7.6(53)	120 ± 10(53)	21.9 ± 3.1(49)	118 ± 6(50)
Lead Adults[d]	69.8 ± 11.6(187)	167 ± 12(124)	64.7 ± 11.7 (216)	155 ± 6 (182)
KENYA				
Birth	3.15 ± 0.47(60)		3.01 ± 0.46(56)	
Infants, 6 mo.	7.1 ± 0.9(60)	62.7 ± 2.7(60)	6.8 ± 1.1(50)	61.7 ± 2.7(50)
Toddlers, 24 mo.	10.5 ± 1.2(53)	79.8 ± 3.6(53)	10.0 ± 0.9(54)	78.7 ± 2.8(54)
Schoolers, 7 yr.	19.2 ± 2.7(93)	113 ± 6(91)	19.3 ± 2.8(76)	112 ± 6(75)
Lead Adults	56.1 ± 6.4(247)	166 ± 6(245)	51.7 ± 5.9(288)	155 ± 6(283)
MEXICO				
Birth	3.15 ± 0.37(39)		2.94 ± 0.40(26)	
Infants, 6 mo.	7.2 ± 1.1(54)	64.6 ± 2.7(54)	6.5 ± 0.9(42)	62.2 ± 2.2(41)
Toddlers, 24 mo.	10.6 ± 0.9(48)	80.1 ± 3.7(19)	10.7 ± 1.3(53)	80.3 ± 4.0(12)
Schoolers, 7 yr.	21.8 ± 3.0(93)	118 ± 6(89)	20.3 ± 3.0(89)	116 ± 6(82)
Lead Adults	66.0 ± 9.8(211)	166 ± 5.8(211)	58.3 ± 9.2(268)	153 ± 5.4(208)

[a] Cross-sectional; women grouped without regard to reproductive states.

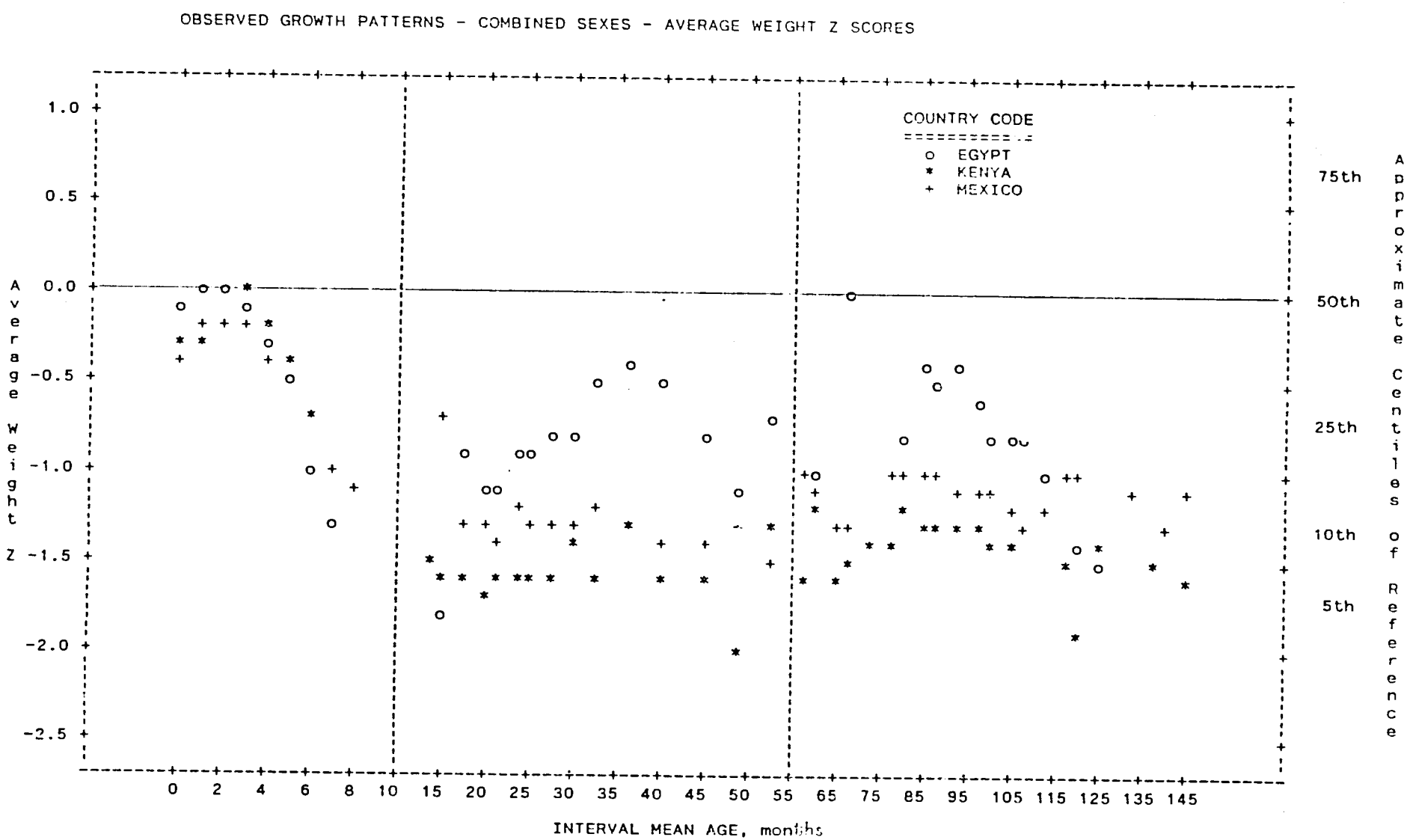
[b] Stature is recumbent length through age 30 mo, standing height thereafter.

[c] Number in parentheses is number of subjects.

[d] Mean ages of male and female adults in years were, respectively: Egypt, 35.3, 29.0; Kenya, 33.8, 31.4; and Mexico, 37.2, 31.6.

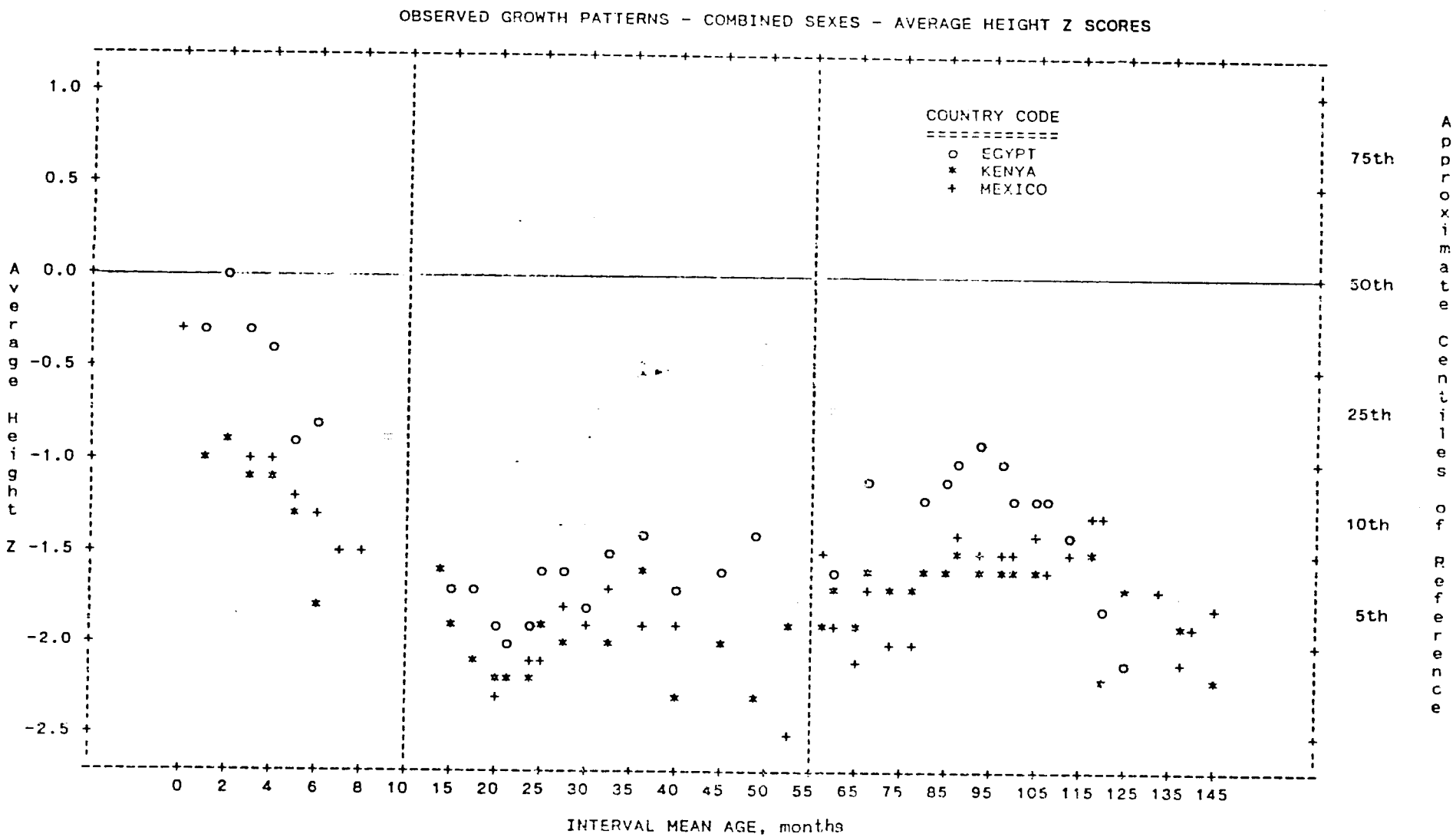
To examine the issue of body size more completely, weights and heights of all members of the study households (targets and non-targets) were used. Figures 8 to 10 portray the weights, heights and weights for heights expressed as Z scores. The children in all three populations have, on average, birth weights which are only slightly lower than those of US children (Z scores close to 0), but between about three to four months and one year of age, the average Z scores for weight fall dramatically. They are surprisingly consistent thereafter, except in Egypt, where the Z scores may continue to fall for a few months after the first year and then to rebound. (Such an interpretation may be erroneous given the high variation in group mean Z scores across all ages for that project.)

Figure 8. Z Scores for Average Weight, by Age and Country



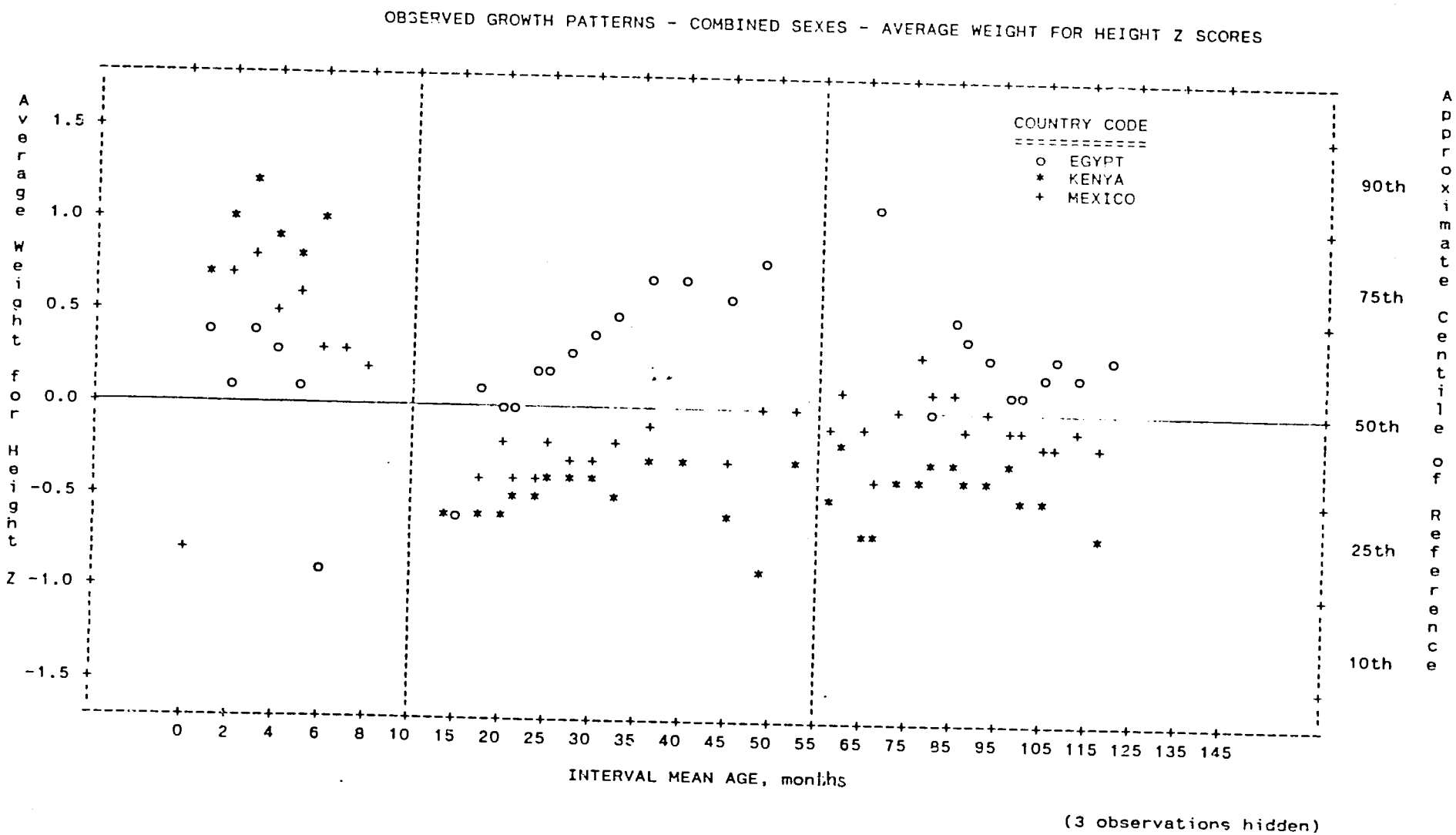
(6 observations hidden)

Figure 9. Z Scores for Average Height, by Age and Country



(8 observations hidden)

Figure 10. Z Scores for Average Weight for Height, by Age and Country



(3 observations hidden)

At eight years of age, boys in Egypt who started with relatively normal birth weights (Z score = -0.1) show a deficit of about 2 kg in comparison to the reference population (Z score = -0.6). In Kenya, the Z scores fell from -0.2 to -1.3 representing a "loss" of growth of about 3.5 kg. Mexico boys moved from -0.4 to -1.2 standard deviations representing about 2.5 kg of foregone growth. If all of the individual data for children from 12 months to 10 years are considered, the best-fit lines describing the Z score in relation to age show changes of only 0.30 standard deviations across nine years for Egypt, 0.35 for Kenya and 0.33 for Mexico. At 10 years of age, this would represent an average of about 1.5 kg of cumulative "catch-up" growth in weight. This may be contrasted with a fall of about one standard deviation during the first year of life in the Egypt children and of about 1.5 standard deviations in the Kenya and Mexico children.

The picture for height is generally similar. By age 30 months, the lag in growth amounted to more than one year in Kenya (i.e., a 2.5-year-old was about the size of a 1.5-year-old American child), almost one year in Mexico and more than six months in Egypt. By the age of eight years, the "loss" of height might represent about 5 cm in Egypt, and as much as 8 cm in Kenya and Mexico. Adult heights, expressed as standard deviations below the US norms for young adults, are generally similar to those seen in study children. (See Table 6.)

TABLE 6

Average Observed Z Scores for Weight and Height at Selected Ages

Project	Weight						Height					
	0m	6m	30m	8y	Men	Women	0m	6m	30m	8y	Men	Women
Egypt	-0.1	-1.1	-0.7	-0.6	-0.6	0.0	–	-0.9	-1.8	-1.0	-1.4	-0.7
Kenya	-0.2	-0.7	-1.4	-1.3	-1.6	-0.8	–	-1.8	-1.7	-1.6	-1.5	-1.4
Mexico	-0.4	-0.6	-1.3	-1.2	-0.9	-0.3	-0.3	-1.3	-1.9	-1.6	-1.5	-1.6

When weight and height are considered together, a different pattern emerges. Children in all three projects have relatively normal weights for their reduced heights. This is seen in Figure 8 where the Z scores scatter around 0. In the Egypt project children, the Z scores of weight for height tend to be higher than in the other projects and in particular, higher than in Kenya. In adults the deficit in weight is quite different from that in height, particularly in women in Egypt and Mexico. While adult height Z scores remain depressed, weight Z scores increased except in Kenya men. On average, Egypt women weighed as much as US women but were shorter.

The variable weight and uniform height relationships among adults indicate that body fatness varied in the three countries. Figure 11 portrays the adult Body Mass Index [BMI=Weight (kg)/Height(m)^2], a measure of fatness, compared with reference data for the United States.[1] In the reference population, BMI increases with age in both sexes indicating increasing fatness; the rise is more steep in women than in men, and BMI levels off or decreases above age 55. BMI of men in Mexico and Egypt is below, but follows the same general trend as the reference through the 54-year age period, after which the Egypt sample BMI shows further increase and the Mexico, a decline. BMI of Egypt women is higher than that of the Mexico sample, and both are higher than reference through age 54; above age 55, BMI is about the same as the reference. The Kenya sample is notable in being much thinner than the reference and failing to show an increase in fatness with time.

[1]Calculated from weight and height data in Abraham, S., C.L. Johnson and M.F. Najjar. Weight and Height of Adults 18-74 Years of Age, United States, 1971-1974. Vital Health Statistics Series 11, No. 211, U.S. Government Printing Office, Washington, D.C., 1979.

Figure 11. Median Body Mass Index for Adults, by Age, Sex and Country

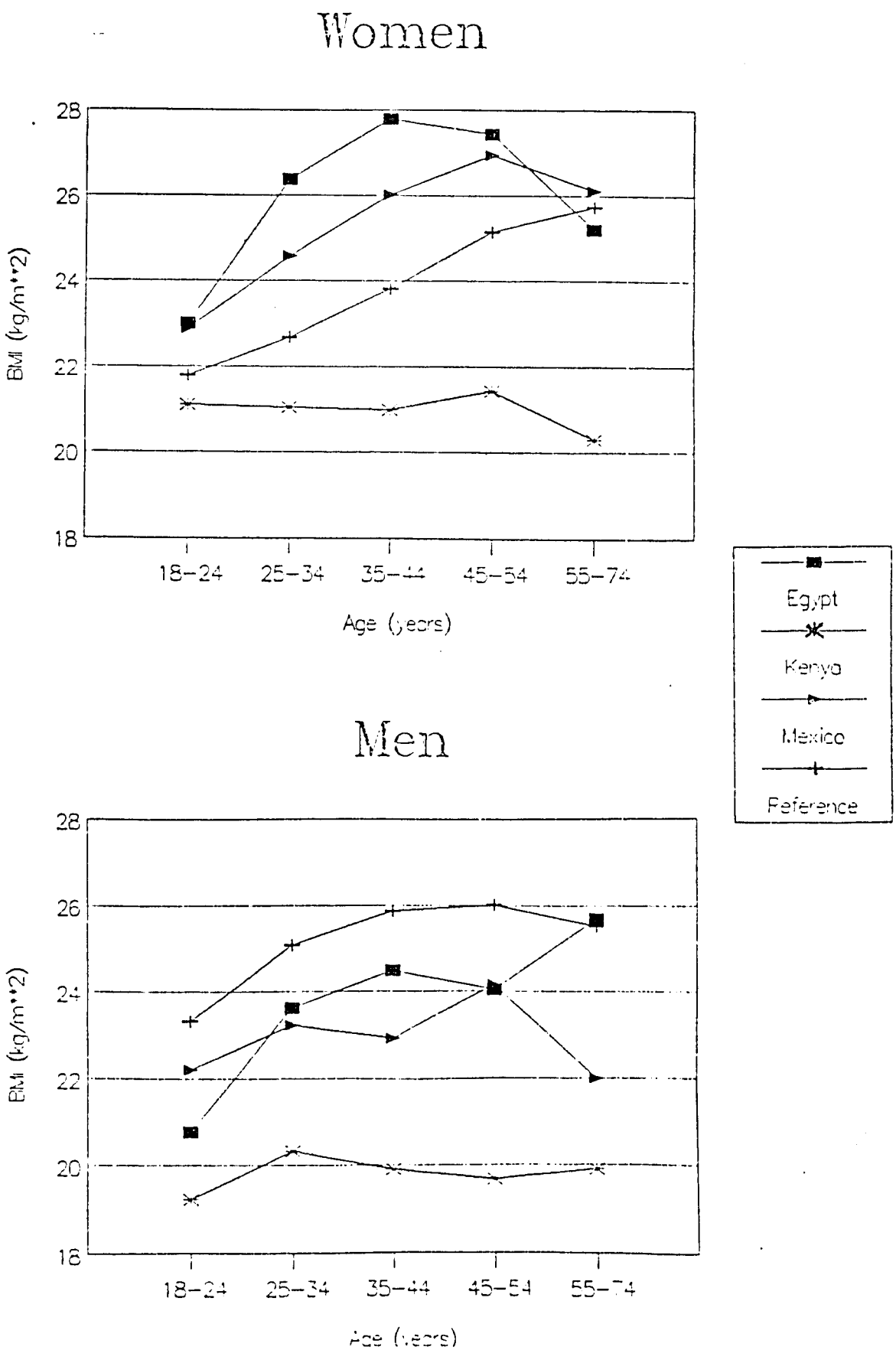
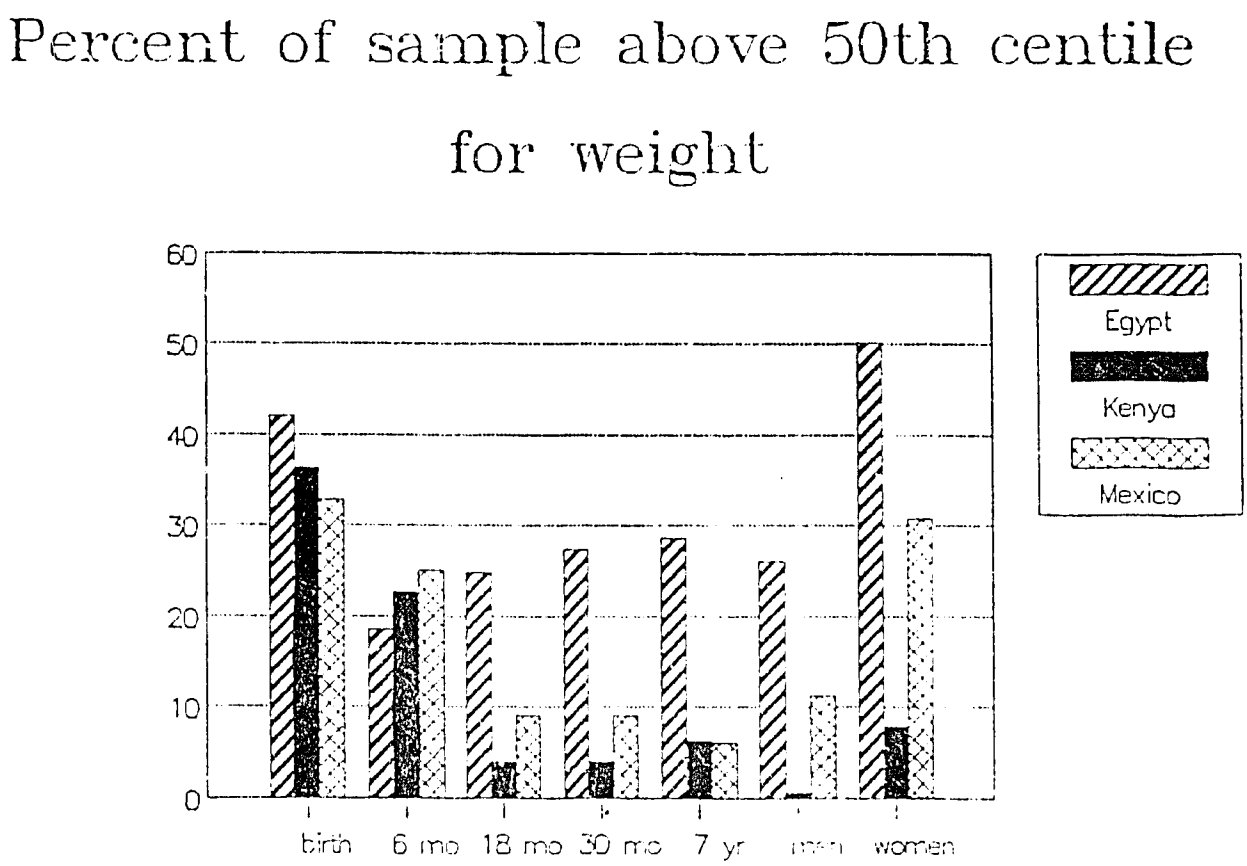
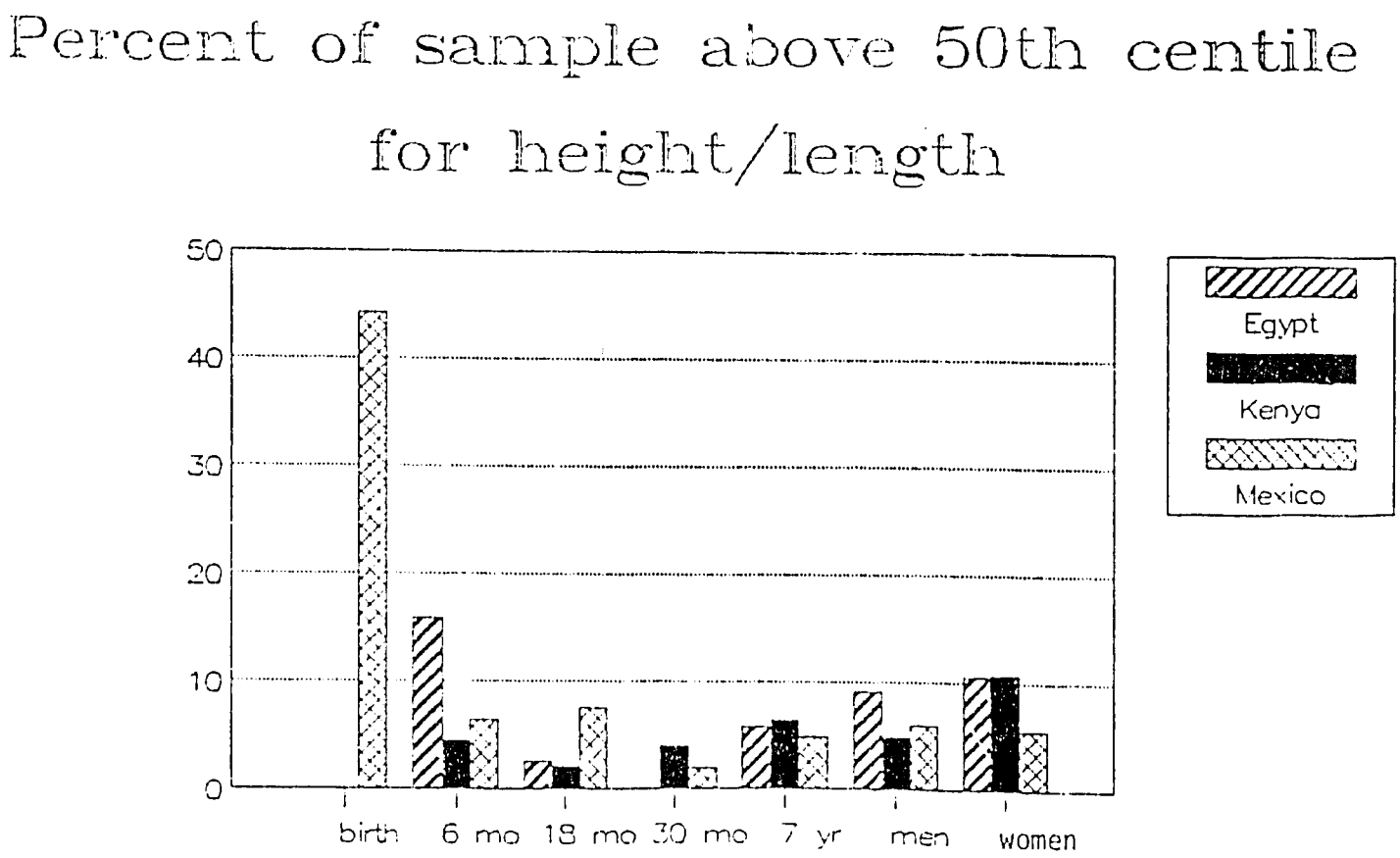


Figure 12. Percent of Sample Above 50th Centile for Weight and Height, by Age and Country





The average values for body size mask a great deal of variability. In each project some 5 to 25% or more of the population are above the average weight of the US reference population (Figure 12). Fewer, but not inconsequential numbers are above the average reference height/length. Subsequent analyses can examine the characteristics of these "positive deviant" individuals and their households to determine what sets them apart from the general pattern of stunting.

Conclusion.

The picture of body fatness is consistent with a conceptualization of food energy intake as meeting or slightly exceeding adult requirements in Egypt and Mexico and being constraining in Kenya. Whatever factors govern adult height must be sought in events earlier in life, a topic to be addressed later in this report.

ILLNESS AND HEALTH

The examination of relationships between intake and health requires an assessment of the environmental conditions, the health background, within which the current illnesses occur. For infectious diseases, the major cause of morbidity, no matter what the individual's susceptibility, experience of the disease depends on exposure to it. Factors that affect exposure include the number and mobility of persons in the household, the presence of vectors (flies, mosquitos, rats), the presence and characteristics of the latrine, access to safe drinking water, and hygienic practices (frequency and timing of hand-washing, etc.). To practice good hygiene requires knowledge of what is good practice and enough soap, clean water and utensils.

Sanitation and hygiene.

Projects attempted to capture information most relevant to the local sanitary conditions by means of direct questioning and observation. Some of what the projects report can be understood intuitively from experience elsewhere -- that children are more often dirty when there are many children in a family (Mexico), that the reception area of a house is kept cleaner than the area where toddlers play (Egypt), that families that are better off economically score higher on many markers of sanitation (Kenya). Of particular interest are the indications that personal perceptions or priorities, a reflection of education and modernity, seem to be the limitation, rather than cash or access. In Egypt, for example, in 60% of the households, water is heated for bathing, but only 1% boil water for drinking; two-thirds of the households have television sets, but only 10% have the refrigerators which would reduce the opportunity for food spoilage.

Each project has constructed a scoring method for its own situation. It is difficult to know if "clean" means the same thing in the three places and, thus, difficult to compare the scores across projects. Several scoring variables exist in common that, in future analyses, may allow more firm conclusions to be reached. The general sense obtained from reviewing the projects one-by-one is that, unlike the situation with respect to food, Kalama is certainly no more sanitary than are Embu and Solis, and that because of the proximity of houses and the presence of the canal, Kalama may provide greater opportunity for the spread of disease.

Parasitism.

One indicator of the general health conditions is the chronic parasite burden. These agents contribute to some acute illness episodes as well. Major infectious agents were known to differ among locations; schistosomiasis was prevalent in Egypt, malaria in Kenya and amebiasis in Mexico.

The Egypt project examined fecal and urine specimens of persons over three years of age. Schistosomes were found in 12% of the population. Some 85% of households had one or more individual infected with parasites and 60% of individuals were infected with various organisms (amoeba, giardia, round worms, etc.). Parasitic infection was greater during the winter than the summer, which was attributed to closer living conditions in the cold season.

Malaria prevalence was seasonal in Kenya, reaching a level of 8% in the rainy season. It was higher in schoolers and adults than in toddlers and infants. Hookworm was very prevalent in a first survey, found in all age groups except infants: toddlers, 6%; schoolers, 36%; male adults, 48%; and female adults, 55%. In a second survey, after treatment was offered, percentage of fecal specimens positive for hookworm was much lower but still 20% in adults. About 2 to 3% of fecal specimens revealed round worm infection, except in schoolers where it was 6% and in infants who were not infected.

The Mexico project reported heavy infection with ameba, giardia and various worms. Among infants, 20% had ameba cysts, but none had giardia; 18% of toddlers had ameba and giardia, and 6% had round worm. The percentage of infestation with ameba increased to 40% by schooler age and was stable at that level in the adult population, along with giardia, roundworm, etc.

Morbidity: methodologic variables.

Some very important issues exist with reference to interproject comparisons of morbidity. The first is a basic difference in the field procedures, and hence the nature of data collected, between Mexico and the other two projects. The Mexico procedure of recording only illnesses observed on the day of interview resulted in underestimation of incidence and prevalence of short term illness. As duration of illnesses increased, the proportional under-reporting decreased. Direct comparisons of the two methods have been offered by the Mexico project for the period when both were in place. A crude adjustment of data has been undertaken for purposes of improving cross-project comparability in this report.

The second difficulty is a potential or real difference in the judgments about the presence or absence of symptoms, and as to what constituted a symptom. Such differences could result from the background training of the interviewers, from community perceptions of illness and hence subject responses to the interviewers, or from the operational criteria developed and standardized within an individual project. The prior training of the interviewer can affect the data recorded, and a physician examining a patient may render a different judgment than if he/she were examining only recorded symptoms. Regardless of who actually conducts the field interview, the recording of an "illness" is contextual. That is, "ill health" may be marked as a departure from "normal health" (the background picture of the community) rather than from "good health" (conceptually a diagnosed situation based on objective criteria). This distinction is implicit in the approach taken in the interviewing. The spontaneous answers to the questions, "Has anyone been ill?" or, "Is anyone ill today?" will be influenced by perceptions of illness in the community. These perceptions, and the degree of interviewer probing of a negative answer, will influence reported morbidity. The Mexico project notes that women are more likely than men to report symptoms and to seek medical advice. There are suggestions that these factors operated across projects to give differences in the meanings of the morbidity variables, particularly between Egypt and Mexico, on the one hand, and Kenya on the other. It has not been possible to develop objective procedures by which "reporting bias" can be assessed across projects.

A third concern is variation in illness intervention. The procedure to be followed upon identification of an illness or injury always presents a problem in field research. It is unethical to withhold treatment that it is within a field team's resources to provide, but intervention, particularly with therapies that would ordinarily not be available to the community, may distort the phenomena under study. Projects took decisions based on their separate circumstances, which may have affected detection, duration, and severity of illness. Generally, professional staff gave first aid, started treatment, or referred the patient to a hospital. In Kenya, suspected malaria was treated with chloroquine after taking a blood smear. All projects agreed that subjects having blood

hemoglobin values below 9 g/dl were to be treated with iron. Minor ailments were treated symptomatically with aspirin, decongestants and antacids. There is evidence in the Kenya data from "second round" screenings that treatment of anemia and intestinal parasites was moderately effective.

Morbidity, incidence, duration and severity in children.

Direct comparisons of morbidity across projects are tenuous for all the reasons cited. Nevertheless, crude comparisons of the incidence of selected diseases, common in children, are revealing (Table 7). The incidence of all three illnesses -- diarrhea, upper and lower respiratory infection -- decreased with age in all three countries. Among infants, boys were reported to experience more illness than girls. Diarrheal disease incidence was two- to three-times higher in Egypt than elsewhere and was higher in Mexico than in Kenya.

The positions are reversed for upper respiratory infection, with Kenya highest and Egypt lowest. Incidence of lower respiratory infection was strikingly high in Egypt infants; for other age groups, Egypt and Mexico show the same incidence and Kenya less. Of these three diseases, diarrhea and lower respiratory infection are thought to have the more profound effects on child growth and development. Thus, children, particularly infants, would appear to be most at risk in Egypt and least in Kenya.

The judgment as to impact of the diseases must consider also the duration and severity of the episodes of illness. With but one exception, duration of illness episodes is longer in Kenya than elsewhere (Table 8). The difference between projects is most notable in diseases of the respiratory tract. The incidence of lower respiratory illness is eight times as high in Egypt infants as in Kenya, but an episode lasts 2.5 times as long in Kenya. For upper respiratory illness, where both incidence and duration are high in Kenya, and almost all children are affected, the prevalence is very high; on any given day, 18% of all toddlers would be found to have an upper respiratory complaint. In Egypt or Mexico, only about 2% would be reported to have such an illness. The surprisingly low prevalence of upper respiratory illness in Egypt and Mexico suggests that a substantial proportion of minor complaints -- "runny" nose and the common cold -- may have gone unremarked.

Severity of disease experience is recognized to be an important variable, and one that is difficult to quantify. Illnesses were intended to be classified by diagnosis as "mild" or "severe" (e.g. common cold is "mild", pneumonia is "severe"), taking into account such factors as age, degree of febrile response, presence of complications and duration in relation to the disease condition (e.g. some skin diseases have long duration but little metabolic impact). The degree of incapacity is a significant criterion, and a qualitative assessment was made of this. Change in food intake was accepted to be an important criterion but could not be included as a component of a severity classification when testing hypotheses involving food intake.

The data presented in Table 9 are the severity classifications as reported by the projects, i.e. classification is based on their different judgmental factors. Kenya and Mexico reported a much smaller proportion of illnesses classified as severe than did Egypt. The Egypt data base codes about half of all illness in target individuals as severe, except infants, where 71% are severe. The implication is that children in Egypt (or adults, for that matter) are not regarded as ill unless the illness is severe. Considering the high incidence of diarrhea and respiratory illness in Egypt infants and the estimate of disease severity, these children appear to be an especially high risk group; Egypt toddlers are at somewhat lower, but still high, risk. On the other hand, whatever problems attach to chronic low-grade illness should be most readily detected in Kenya.

TABLE 7

Average Incidence of Specified Disease Categories Among Longitudinal Infants and Children in Egypt, Kenya and Mexico
(Episodes per 1000 person days)

Target Type	Sex	EGYPT PROJECT N	EGYPT PROJECT Average Incidence	KENYA PROJECT N	KENYA PROJECT Average Incidence	MEXICO PROJECT N	MEXICO PROJECT Average Incidence	MEXICO PROJECT Adjusted[a]
A. Diarrhea								
Infants	M	30	9.9	50	2.6	34	3.6	4.5
	F	24	7.4	43	1.5	35	4.0	5.1
Toddlers								
	M	41	9.4	42	2.9	29	1.8	2.9
	F	42	8.1	49	4.4	26	3.0	4.9
School.								
	M	22	0.68	72	0.27	55	0.11	0.15
	F	19	0.99	57	0.14	54	0.19	0.27
B. Upper Respiratory Tract Illness								
Infants	M	30	5.7	50	15.4	34	6.0	8.1
	F	24	4.6	43	16.9	35	4.8	6.5
Toddlers								
	M	41	3.8	42	16.1	29	4.3	6.0
	F	42	3.8	49	16.7	26	3.7	5.2
School.								
	M	22	2.2	72	6.6	55	1.1	1.9
	F	19	0.71	57	4.6	54	1.6	2.6
C. Lower Respiratory Tract Illness								
Infants	M	30	8.8	50	1.0	34	4.0	4.5
	F	24	8.3	43	0.49	35	2.7	3.0
Toddlers								
	M	41	3.4	42	0.58	29	3.1	3.6
	F	42	3.8	49	1.1	26	2.4	2.7
School.								
	M	22	0.96	72	0.61	55	0.47	0.60
	F	19	0.16	57	0.43	54	0.93	1.2

[a] Adjusted to take into consideration the underreporting of short term illnesses in Mexico; see text.

TABLE 8

Mean Duration Of Illness Episodes, days

	Egypt	Kenya	MexicoA[a]	MexicoB[a]
Diarrhea				
Infants	5.5	7.0	6.4	5.6
Toddlers	4.4	6.1	5.4	4.1
Schoolers	7.0	4.8	6.6	4.0
Upper Respiratory				
Infants	5.2	18.9	4.9	5.1
Toddlers	5.9	16.1	6.2	4.0
Schoolers	.4	14.2	5.4	4.0
Lower Respiratory				
Infants	6.2	15.2	6.5	6.3
Toddlers	6.4	11.2	6.2	6.1
Schoolers	5.7	7.1	5.9	5.2

[a] Mexico A = project methodology; Mexico B = CRSP methodology.

TABLE 9

Comparison of Frequencies of Application of Severity Codes
by Target Type
(% of reported morbidity episodes)

	EGYPT		KENYA		MEXICO	
Target Type	mild	severe	mild	severe	mild	severe
Lead Males	46	54	94	6	96	4
Lead Females	52	48	96	4	95	5
Schoolers	54	46	95	5	91	9
Toddlers	42	58	94	6	[illegible]	[illegible]
Infants	29	71	96	4	100	

Morbidity in adults.

Illness of adults is of a different character and, within a project setting, incidence is lower in adults than children. At least in Mexico, however, illnesses of mothers and infants are closely related. In Egypt, upper respiratory and gastrointestinal disease categories account for over half of adult illness; genitourinary tract problems are identified as a significant problem in women. The Mexico project reports the presence of bacteria in the urine of about 25% of pregnant and lactating women, a problem that contributes to the genitourinary illness episodes which are related to

reproductive status. In Kenya, upper respiratory diseases account for about 20% of adult illness, but there is little diarrhea; 10-15% of adult disease episodes are due to malaria. Nonspecific chest and back pain and headache make up 5 to 9% of Kenya adult illnesses, musculoskeletal complaints may be work-related, and women especially complained of backache during pregnancy.

Personal habits contribute to variability in adult disease experience. Abuse of alcohol is a likely contributor to the 46% incidence of trauma -- accidents and injuries -- and 5% incidence of psychiatric disorders reported in the medical history of Mexico men, as well as the red blood cell abnormality (macrocytosis) commented on above. In contrast, use of alcohol is believed to be extremely rare in Kaiama.

Motivated by reflection on the drought experience and hard conditions of life in general, the Kenya project looked into the prevalence of anxiety and depression in adults. Responses indicating some distress were twice as frequent in women as in men and approached clinical significance in 13% of women and 4% of men. For men, use of alcohol may be an escape, one which creates its own pathology.

Morbidity as an outcome.

It has not been possible to the time of this writing to examine statistical relationships between food intake and morbidity across projects. This task requires extensive reorganization of the archived data and,in some cases, reference to field forms. The projects themselves have only briefly explored this hypothesis and only for toddlers in any depth.

What is now clear is that the general background of disease is high in Egypt, reflected in the high burden of parasitism and the incidence coupled with severity of disease in infants and toddlers. Food energy intake appears to be adequate, and average consumption of animal products is ample (if not generous in comparison with fully developed countries). Under these conditions, it seems unlikely that an effect of food intake on morbidity could be identified within the project, and none was found. The project did find, however, that children in whom episodes of diarrhea progressed in severity were lighter in weight and shorter before-the onset of the illness than those in whom there was uncomplicated recovery. The factors responsible for this relationship have not yet been identified and the relationship did not hold for lower respiratory illness.

Kenya presents a different situation. The population seems beset by chronic low-grade illness but has little severe illness. Food energy, fat and animal protein intakes are low. A most dramatic effect ascribed by the project to food intake was seen in the period of drought-induced food scarcity. There were 1.7 times as many morbidity episodes in the months July-December, 1984, as in the same months of 1985, and the prevalence of clinically severe protein-energy malnutrition among children rose from 2% to 6%. Looking across the two years as a whole, the project found weak positive correlations between morbidity and all food intake variables at some periods in toddlers; the project suggests that better fed children were more active and mingled more with other children, increasing their exposure to infection. Food would be more likely to be a factor in serious illnesses that have associated metabolic costs but no consistent correlations were detected. The statistical problem with this data set is formidable given the low frequency of serious illness and the high variance in intake factors.

In Mexico, infant morbidity in the first three months of life was negatively related to maternal energy and protein intake during pregnancy and, at three to six months of age it was positively related to maternal intake during lactation. The project report attributes the latter, anomalous finding -- that infants were more often ill where maternal diet was better in the 3 to 6-month period -- to the mother's attentiveness to the condition of her baby being better in better-fed mothers. The Mexico project has reported that toddlers with more episodes of diarrhea had lower consumption of animal foods than those without diarrhea.

All projects have looked at morbidity as a factor confounding growth. Such an effect might well be expected by reason of depressed food intake, if no other. Only diarrheal disease was shown to affect growth negatively (in infants in Egypt and toddlers in Mexico). The effect was on weight but not on height of toddlers. Maternal illness during pregnancy was shown to depress maternal weight gain in Kenya and Mexico and infant birth weight in Kenya.

Mortality.

The first year of life was hazardous. In Egypt, ten deaths occurred among target infants; five additional deaths occurred in the second six months, bringing the death rate to about 140/1000 live births. This number is large enough to warrant an exploration of associated characteristics. Infant mortality also was high in households studied in Mexico, but none of the infants studied was in the longitudinal infant sample, so there is little information about them apart from household characteristics. Three perinatal deaths were due to prematurity, two infants died of pneumonia and five others from various causes. In Kenya, there were two stillbirths and three perinatal deaths; there were no other deaths among target infants.

Deaths of three toddlers in the Mexico project were due to infectious diseases. One schooler drowned and two teenagers died of trauma. There was no consistent pattern of disease among the eight male adults who died. Two of the three male adults and the one schooler who died in Kenya had liver problems (hepatoma, hepatitis). The other adult death was due to laryngeal cancer. Exposure to an environmental agent (aflatoxin contamination in food and/or other) is reported to be likely.

Conclusions

The diseases of early childhood were frequent and severe in Egypt and many infants died. Mexico ranked second and Kenya a distant third in this regard. Frequent chronic low-grade illness was characteristic only of Kenya. Since food availability was not likely to be limiting in Egypt or Mexico and it was in Kenya, an explanation for the morbidity difference must be sought in parental behavior, environmental sanitation and/or the health care system.

Although the effect is less than was expected from other reports, diarrheal disease did affect toddler growth adversely. This effect is due, in part, to its effect on food intake.

Heavy consumption of alcoholic beverages is a contributor to health problems of men in Mexico and perhaps in Kenya. It may also affect family well-being in ways yet to be examined.

COGNITION AND BEHAVIOR

Projects measured several components of psychological function. The battery of tests included measures of intelligence that have been widely used and standardized. Structured observation of mother-infant and mother-toddler interactions and of schoolers in the playground and classroom were intended to capture elements of behavior. (The mother-child observations served multiple purposes in indicating maternal care-giving skills.)

Projects fully recognized that there were cultural differences associated with the implementation and application of even tests as widely used as those selected for the CRSP. Projects made culture-specific modifications of the instruments and of the components of the tests administered, and adopted different approaches to scoring the results; none standardized the results against North American norms. Only the toddler data have been examined in any depth by all projects and much remains to be done with that data set. Cross-project evaluation has, of necessity, focused on the few discrete measures that exist in common between projects and has utilized scores as reported by the projects.[1] Examination of the results of less common tests or individual items of the well-known ones, and of the behavioral observations awaits further interpretation to assure that the same components of behavior/cognition have been measured across projects.

The most striking finding, across projects and age groups, is an association between mental test scores and body size. As expected, children who are heavier and/or taller generally show better test performance than smaller children. This implies that whatever factors affect childhood growth also affect mental function.

Infants

The Brazelton Neonatal Assessment Scale (BNAS) was administered to infants within 7 days of birth as a measure of interactive behavior. It should be less affected by cultural differences (except as these affect the test-givers' perception) than tests given to older children or adults. In all projects, one or another component of the BNAS correlated with birthweight or birthlength but the specific components varied. In Egypt, the association was with the orientation component; in Kenya, the reflex, motor and habituation components correlated significantly with weight; and in Mexico, autonomic stability was related to both length and weight. (The reflex component was weakly correlated with birthweight in Egypt and the motor component with birthweight in Mexico, but the number of infants was too small for correlations to reach statistical significance.) In Mexico the relationship with length was stronger than that with weight. (Associations with birthlength were not tested in Egypt or Kenya because of missing data.) Thus, infants appear to be differently endowed at birth, with size being a marker of nervous system function.

Tests of both motor and behavior functions were administered when infants were six months old but the data have not yet been analyzed. Future analysis should determine whether or not the BNAS predicts later development, independent of other factors likely to affect development in early life. Factors of record but yet to be explored include maternal diet and behavior, infant feeding, and morbidity.

Toddlers

The Bayley Mental Scale presents a series of items of increasing difficulty developed according to U.S. norms. Typical items include measures such as the ability to build with blocks or to name objects. The usual method of testing is to continue with a designated series of items (which differ depending on the age of the child) until the child first fails an item. The Egypt project gave the test in the usual manner, while the Mexico project deviated from the standard procedure by continuing testing even after an item was failed. The highest item passed is the score. The range of scores is, thus, higher and much narrower in Mexico data as archived than in Egypt. The coefficient of variation in the Mexico 30-month Bayley Mental Test data is only 1%; it is 6% in the Egypt data. The Kenya project reported its findings as the total number of items passed from a selected series administered; the coefficient of variation in the Kenya summated scores is 18%. Although in principle the larger range of scores in Kenya should allow easier identification of factors associated with test scores, the high variance ratios in nutrient intakes may tend to obscure these relationships.

---

[1]Projects have not uniformly reported on such data quality issues as interviewer bias, within-subject consistency across ages (18, 24 and 30 months in toddlers), etc.

In cross-project analyses, no significant associations were found between the reported 30-month Bayley Mental Test scores and dietary intakes averaged over the 18-30 month age period. Mexico, however, reported a significant effect of animal protein intake during the 3 months preceding the test.[1]

The Bayley Mental scores were positively correlated with body weight in all three projects and with length in Mexico and Egypt. The larger children had the better test performance.

There is published evidence that indicates iron deficiency and anemia to be detrimental to psychological functioning. The 30-month Bayley Mental test scores were examined with blood hemoglobin values above and below the international standard used as a dichotomous variable (Kenya and Mexico, 11.5 g per dl, Egypt 11.0 g per dl). No difference was found. The procedure was repeated with the standard lowered by 1.0 g per dl. Bayley scores were insignificantly higher if hemoglobin was above 10.5 g/dl in Kenya ($p=.12$) and 10.0 g/dl in Egypt ($p=.06$). In the Egypt sample, toddlers with higher hemoglobin were significantly taller and, using the 11.0 g/dl standard, heavier.

The projects' reports note a number of non-dietary factors relevant to Bayley Mental test performance. Both serious and low-grade illness during the 13-24 month period were negatively related to the 30-month Bayley score in Kenya and morbidity adversely affected the scores at the 24-month age in Egypt. Morbidity was not related to test scores in Mexico. Toddler test scores were not related to maternal literacy in Mexico or Kenya (this factor was not tested in Egypt) but father's literacy was related to toddler test scores in Kenya. Interestingly, Kenya father's intelligence test scores were not correlated with toddler scores but the mother's were. Household socioeconomic status (SES) was a significant factor in test results at 24 but not at 30 months in Kenya and SES was correlated with paternal literacy. In Mexico, child appearance (a hygiene measure) was an important predictor of 30-month scores, tending to displace dietary factors in multivariate analyses. The appearance measure also correlated with SES.

Certain of the behavioral observations of both the child and the family provide clues to the factors that affect psychological function in toddlers. The Egypt project remarks that a child's characteristics affect how others respond to her or him.[2] In Egypt, the amount of child vocalization (interactive or attention-getting) was correlated with the toddler's energy intake (kcal/kg). Lower levels of food consumption were associated with more frequent caregiving by Egypt siblings (in contrast to mothers and other adults) and more active children were given less food. In Mexico, both intakes of animal calories and protein were associated with more verbal interaction with the caregiver and with less time inactive and more time involved in recreation and in being cleaned. In Kenya, the multiple factors most strongly associated with the Bayley scores included the child's social interaction and caregiver's response to child vocalization. The amount of time the child was held was a negative factor in Kenya, which the project suggests may be because children who are held are ill or simply less accomplished.[3]

The Bayley Motor Scores reflect the child's physical performance, coordination and balance. Only Mexico and Kenya projects administered this test at 30 months, and Mexico project has not commented on the outcome. In Kenya, the Motor Score was correlated positively with both body weight and length. It was associated negatively with illness during the period 18-24 months of age, but not 24-30 months. The Mexico children scored better than Kenya toddlers on the motor tests except for distance jumping. This suggests that the Mexico toddlers were more advanced in development which could reflect their somewhat better diets.

---

[1]See Mexico Final Report and Pelto, G.H. et al. FASEB J 2:A1204, 1988.

[2]See Egypt Final Report and Wachs, T.D. et al. Presentation, 6th International Conference on Infant Studies, Washington, D.C., 1988.

[3]See Kenya Final Report and Sigman, M. and C. Neumann. Presentation, 6th International Conference on Infant Studies, Washington, D.C., 1988.

Schoolers

Two components of the Wechsler Intelligence Scale for Children (Digit Span and Block Design) plus the Raven's Progressive Matrices were administered to schoolers by all projects (Table 10). Cross-project analyses were carried out on the longitudinal sample of subjects for whom dietary, anthropometric and cognitive data were available. In Kenya, performance on the tests was strongly related to body weight and only slightly less so to height and body mass index. In addition, performance on the Block Design and Raven's Matrices tests was related to animal protein intake per kilogram of body weight and the Raven's to fat intake per kilogram. In Mexico, weight, height and body mass index were significant factors in relation to the Block Design test; both animal protein and fat intakes per kilogram were correlated with Digit Span performance. In Egypt, results on the three tests were slightly less consistent and performance was unrelated to anthropometric or to dietary factors in the small group of subjects with complete data (n=24).

TABLE 10

Cognitive Scores for Adults and Schoolchildren
(CRSP Cross-Sectional Samples, Mean and Range)

	N*	Digit Span Forward	Digit Span Backward	Block Design	Raven's Matrices
Adult Males					
Egypt	81-82	4.6(0-7)	2.8(0-5)	4.3(0-11)	18.1(7-33)
Kenya	245-304	4.0(0-10)	3.6(0-8)	6.8(0-32)	22.3(8-55)
Mexico	199-200	4.0(0-10)	3.5(0-9)	13.0(0-46)	16.7(7-33)
Adult Females					
Egypt	140-143	4.0(0-6)	1.8(0-3)	2.9(1-10)	15.1(5-35)
Kenya	201-309	3.7(1-9)	2.9(0-9)	5.9(0-25)	18.9(6-50)
Mexico	244	3.4(0-8)	2.7(0-6)	10.0(0-36)	14.4(2-29)
Male Schooler					
Egypt	99(56)	4.2(0-7)	2.4(0-6)	6.2(1-11)	14.8(9-25)
Kenya	24(79)	2.8(0-8)	1.7(0-5)	5.1(0-31)	12.5(0-32)
Mexico	146(90)	2.3(0-8)	2.2(0-6)	6.9(0-27)	13.0(6-24)
Female Schoolers					
Egypt	103[64]	3.9(0-8)	1.5(0-6)	5.2(1-11)	13.1(7-23)
Kenya	201[65]	2.8(0-8)	1.8(0-6)	5.0(0-19)	13.0(6-30)
Mexico	139[84]	3.4(0-8)	2.0(0-5)	6.6(0-38)	12.7(4-22)

*N=number of observations. Adults were tested once. There were repeated tests of children; number in brackets is number of subjects.

Boys scored better than girls in Egypt, but this was not so in Kenya and Mexico. The Mexico project reported that test scores varied with the grade in school (children of this target group had 0-3 years of schooling). The sex difference in Egypt may already reflect the restricted educational opportunities for females noted previously.

Adults

Components of the Wechsler Adult Intelligence Scale were administered to adults by all projects. Scores on the two components that are similar to those administered to schoolers, plus the Raven's Matrices scores, are shown in Table 10. By adulthood, the sex difference in test performance was evident in all three locations. The difference in schooling is doubtless a factor in the test-taking skills and years of school attendance was shown to be a significant variable in Mexico adult scores. Egypt adult scores were somewhat better than schoolers of the same sex, except for the Block Design. In Kenya and Mexico, adults scored consistently better than schoolers on all measures. Factors that relate to adult intelligence scores remain to be examined.

Conclusions

Size is a consistent indicator of psychological functioning in the newly born and toddlers. Size is still a marker in schoolers in Kenya and Mexico and the quality of the schooler diet (amount of animal protein and fat) is associated with test performance. Many factors in the household environment are related to psychological function in toddlers. Since these factors are often related to one another, further analyses are required to pinpoint meaningful predictors.

To the extent that food intake affects growth it will affect mental function. It remains to be determined if nutrient intakes consistently affect performance beyond any effect on growth; the evidence suggests that any such effects will be very difficult to unravel statistically.

DETERMINANTS OF GROWTH AND ATTAINED SIZE

Anthropometric data reviewed above suggest that growth failure occurs within the first year in all projects though not necessarily for the same reasons. The data suggest also that there is minimal catch up after that time. When one speaks of "growth failures", "losses" and "foregone growth", there is an implicit assumption that if there were no environmental constraints, on average these children would have exhibited weights that distributed around the US mean. Although that assumption is undocumented for the specific cases of these countries and village populations, it is reasonable as a working assumption. The CRSP offers data that can contribute to an understanding of why the genetic potential for size is not expressed in the three, very different, settings.

A logical starting place is to look for effects of food intake in toddlers, the data set most completely described by the projects thus far and an age group frequently targetted for intervention programs. Also, growth rate normally is sufficient in this age group to examine growth, as different from attained size.

Toddler intake and growth.

The relationship between a toddler's intake and his or her achieved height and weight and the slope of change (rate of gain) in height and weight between 18 and 30 months of age was examined. Several small but significant associations between average yearly nutrient intake and achieved size were found.

Dietary variables were not significantly associated with weight or weight gain in either Egypt or Kenya. In Mexico, 30 month weight was predicted by protein calories as a percent of total calories (r=.47), animal protein (r=.43), and fat calories as a percent of total calories (r=.37). With three diet variables (animal percent protein, total protein and animal protein) in a regression model, 39 percent of the variance in 30 month weight could be predicted. Animal protein and animal protein as percent of calories also predicted the rate of weight gain in Mexico toddlers. However, two

female toddlers in Mexico had large intakes of animal protein (but not of energy) and were also taller and heavier than average. Intakes by other members of these toddlers' households also showed high animal protein values, so it is likely these toddler values are correct. Nonetheless, if these two children were omitted from analyses, the significance of animal protein in predicting body size is either greatly reduced or disappears entirely. The two individuals exerted undue influence and hence the interpretation of these, and some other analyses from the Mexico project's data set, is very difficult.

For the Kenya toddlers 26 percent of the variance in height at 30 months could be predicted by animal protein as a percent of total protein, total calories and protein as a percent of calories. Thirty-four percent of the variance in Mexico toddler heights was predicted by animal protein calories as a percent of total calories, average protein and average fat intakes. Animal protein intakes were also predictors of the rate of gain in height for Mexico and Kenya toddlers. Average fat intake was the only dietary variable associated with height slope for Egypt toddlers, but a regression model with eight dietary variables did not significantly predict height slope.

An indication of the general magnitude of the effect of small but biologically realistic differences in food intake may be portrayed by calculations based on one of the regression models. In this model, energy intake, total protein intake, animal protein intake, fat intake, carbohydrate intake, sex of the child and a variable representing proportion of months during which the child was still being offered breast milk were used to predict weight or height at 30 months, or the slope of change from 18 to 30 months. This model can be used to provide a crude estimate of the effect of a 100 kcal per day change in intake. The results are shown in Table 11 for a simulation in which the additional energy was supplied by foods with the same type of composition as the existing diet. The model predicts that a 100 kcal per day change in energy intake would significantly affect attained weight and length of Kenya toddlers, but not the Egypt or Mexico children. These simulations were run also with hypothetical additions of 100 kcal as milk or as rice to test the effects of adding fat and animal protein (milk) or a very low fat, relatively low protein source of carbohydrate (rice). As expected, the effect on length at 30 months increased with milk and was lower with rice than with the usual diet. However, the variance of the estimates increased so sharply that only in Mexico could changes be said to differ from zero. When the two unusual Mexico toddlers were removed, the effect disappeared.

TABLE 11

Predicted Change in Size Parameters per 100 Kcal/Day of Usual Diet
Mean (SE)

Outcome Measure	Egypt	Kenya	Mexico
Weight at 30 m, kg	0.04 (0.09)	0.23* (0.08)	0.09 (0.08)
Length at 30 m, cm	0.32 (0.24)	0.56* (0.19)	0.24 (0.23)
Slope of Change:			
Weight kg/y	-0.06 (0.07)	0.07 (0.04)	0.05 (0.05)
Length cm/y	0.15 (0.16)	0.19 (0.12)	-0.06 (0.12)

* Significantly different from zero, $p < 0.01$.

Results such as these must be interpreted with great care. It is not safe to assume that in a real intervention the effect would be as portrayed above. However, the predicted magnitude of effect seen in Kenya is consistent with the low level of anthropometric response seen in operational preschool food distribution programs wherein subjects have not been selected as having particularly low weight.

The results of the simulation are also consistent with the impression gained by comparing measures across projects. Reported food intakes are lower in Kenya than in either of the other projects. The body sizes are more depressed in Kenya than in the other projects. The adults in

Kenya do not show indication of progressive fat deposition as they do in the other projects. It is consistent to suggest that in Kenyan children, current food intake is a factor that is limiting physical growth.

Parental size, maternal diet and growth of children

It would be useful to be able to describe, in potentially operational terms, the situations in which children are found to be at risk of growth failure, that is, to predict the households or families at risk. To this end, a series of analyses was undertaken to see if parental body size or nutrient intake might associate with child size (height or weight Z scores at given ages) or with growth rates (measured as the slope of change in Z scores in individual toddlers and schoolers in the longitudinal samples.)[1] Achieved sizes were strongly predicted by the height and weight of the mother and father. The most consistent relationships were with the mother's size. These relationships can be described by the proportion of the variation in child size that can be explained by the combination of maternal and paternal sizes (Table 12). The effects were in the same direction in all analyses: bigger parents beget bigger children. When data were combined across projects in a single multivariate model including country as a classification variable, it was demonstrated first that there were significant differences in the achieved sizes of toddlers across countries (country was a significant variable). However, when parental sizes were included in the models the country effect disappeared. Much, or most, of the differences in sizes of toddlers between projects, as well as within projects, could be explained by parental characteristics.

TABLE 12

Proportion of Size Variance of Children Explained by Maternal and Paternal Height and Weight (Longitudinal CRSP Sample)

Age of Child	Weight Z score[a]			Height Z score[a]		
	Egypt	Kenya	Mexico	Egypt	Kenya	Mexico
Birth	12%	11%*	7%	-	-	16%
6m	6%	14%**	29%**	66%	17%*	28%**
30m	19%	20%**	21%**	18%	20%**	51%**
8y	37%*	26%**	19%**	33%*	21%**	17%**
Estimated 24m[b]	26%**	15%**	15%**	40%**	16%**	14%*
Estimated 8y[b]	41%	31%**	19%**	21%	24%**	17%**

[a] High, but non significant, values must be interpreted with care since they are usually based on very small numbers of individuals. One or two very different persons can cause the high values. Statistically significant values are indicated by asterisks (* $p<.05$; ** $p<.01$).

[b] Values estimated from regressions of weight or height on age for each individual. These can be seen as age-adjusted values for each individual.

Inclusion of sex of the child in the regression studies explained little additional variance. Girls did as well, or as poorly, as did boys. It appears that, in these populations, gender bias in child care or feeding was not a factor that exerted major effect on growth and development. (Boys, of course, were bigger than girls but when this expected difference in size was controlled by use of Z scores, they were quite similar in their growth patterns).

[1] Details of these analyses are presented in Appendix D.

In a search for measures of the environment that might influence growth, "diet quality" variables were chosen to serve as markers of the family diet and as probable indicators of the household environment more generally. Two such markers were chosen, the percent of energy coming from fat and the percent of energy coming from animal source proteins in the maternal diet. The ratios were calculated from all dietary data collected for each mother during the whole of the study -- both before and after the time period in which child growth was being measured. For the Mexico project, only dietary data collected with the methodology in use after January 1, 1985 was examined; however, this measure was used in relation to growth measures collected in the same household before, as well as during, 1985.

The dietary variables were included in regression models instead of, and in addition to, the measures of adult size described above as predictors of child size at different ages. In Egypt, the household dietary variables had no appreciable effect in explaining variance in child size. In Kenya, they had small, but relatively consistent, effects on achieved height and, to a lesser degree, weight. In Mexico, the household dietary quality variables had quite consistent and substantial effects, explaining as much as 10-20% of the variance in achieved heights and weights in toddlers and schoolers. However, this was not completely independent of the variance explained by parental size To some degree, both diet and parental size were representing the same things.

The scatter diagrams presented previously (Figures 8-10) imply that most, if not all, of the growth failure took place within the first 12 months of life. Yet examination of the slopes of change in weight or height Z scores within the toddler and schooler longitudinal samples shows that individual children differ in their growth rates. If the parental and household variables are exerting their effects during these periods, rather than, or as well as, during the first year of life, it might be expected that they would associate with the slopes of change in Z scores. This was examined in regression models of the type employed above. Only in Kenya could the slope be predicted. The diet quality variables (in toddlers) or dietary measures and parental size (in schoolers) explained significant proportions of the variance in height slopes but not the weight slopes. [1]

It may be that the relationships between family measures and child growth are stronger than those between the child's own intake and growth in the toddler period. This may be true even for the Kenya project since the apparent influence of the parental size and maternal dietary variables is stronger than that seen between toddler intakes and achieved size. It would be desirable to include both parental variables and toddler intake variables in the same models to be sure about relative strengths of associations. This has not been done.

Perhaps the most telling argument in completing this picture is the stability of the pattern of slopes of change.As discussed previously, a normally growing child would exhibit no long-term change in Z score; there might be short-term discrepancies (due to illness, the timing of the pre-pubertal growth spurt, etc.) but across longer periods the Z scores would vacillate around the same mean representing the "stable" size of that child. The situation portrayed in Figures 8 and 9 suggests that the long-term slope of Z score change after the first year is essentially 0. Within short (one year) windows of the toddler and schooler age groups, there is evidence that growth rates vary. Nevertheless, the mean Z scores of schoolers are remarkably similar to those of younger children (and, for height, to those of adults), and there is no indication that the schoolers are more variable than the toddlers in their Z scores. That is an important observation. If the short-term differences in slopes of weight or height increase persisted within the individuals, over time the group would become more diverse. This is not the case. The only plausible explanation is that in these environments, as they are now and appear to have been for a long time, the gains (or losses) in one period must be offset by losses (or gains) in another period within the same child.

---

[1] It is possible that the Kenya project effects are influenced by the occurrence of the food shortage associated with a regional drought. This has not been controlled in the present analyses. Both food intake and weight gain fell in schoolers in this period of restriction. However, it was shown also that there was no demonstrable effect of the famine period on the weight increments of toddlers (or on the variability of weight in these toddlers, i.e. there was no indication that some were being severely affected while others escaped).

Conclusions

Maternal diet variables - - the percent of energy from fat and animal source proteins - - predict the size of toddlers and schoolers in Kenya and Mexico, but not Egypt, indicating that household diet is one of a constellation of factors that affects child development.

In Kenya, provision of more of the same diet is predicted to have a small growth-promoting effect. In Kenya and perhaps in Mexico, the presence of animal source foods in the toddler diet also is related to height.

Parental size is a significant predictor of children's sizes across and within projects. The effect is stronger and more consistent than the effect of maternal dietary variables. These markers -- parental size and maternal diet -- carry predictive power throughout the age span and hence will enable further studies of factors affecting growth across the whole span of ages, not just the longitudinal samples.

Characteristics of the parents may in turn represent characteristics of a stable and constraining environment in which both parents and children have developed. Studies of secular trends in heights and weights suggest that it may take several generations of improved conditions before weights and heights achieve the near-maxima representing genetic potential

PREGNANCY, LACTATION AND INFANCY

In seeking an answer to the question of why growth and development fail so early in life, it is logical to look to the mother, to the factors that affect her well-being during pregnancy and lactation and that determine how she nurtures her infant.

An evaluation of reproductive outcome for the mother would, rightly, consider her condition during the period of reproductive rest as well. For the women in Solis, Embu and Kalama, however, this is almost irrelevant; pregnancy and lactation approached a continuous process, many women becoming pregnant while another baby was still at the breast (Table 13). The sample of women who were neither pregnant nor lactating (NPNL) is older (and, in Egypt and Mexico, heavier) than the women in the longitudinal pregnancy samples and, thus, has limited ability as a "control" group. There is a scattering of data for women in the first trimester of pregnancy. Egypt pregnant women were about three years younger than in the other projects and had had fewer previous pregnancies; there were no primiparous women in the Kenya sample, and very few in the other projects.

TABLE 13

Maternal Age, Parity, and Birth Interval
(Mean ± Standard Deviation)

	Egypt	Kenya	Mexico
Age, years	26.6±6.3	30.6±5.4	30.3±6.3
Parity	4.0±2.8	5.5±2.8	6.2±3.0
Birth Interval, months	29.5±9.9	31.6±9.3	24.5±8.3

The sample populations of pregnant and lactating women in the three countries differed in at least two respects that are thought to affect reproductive outcome. Firstly, the Egypt women were heavier in relation to height than were Mexico women, who were heavier than Kenya women (Table 14). The second significant difference among projects is the level of food energy intake (Table 15), where the rank ordering across projects is consistent with the general intake pattern

described earlier. All three samples include some women who were obese and others who were thin, but the Egyptian and Mexican women were, on average, respectively, about 10 and 5 kg heavier for their heights than the Kenyan women (who would be considered lean but not excessively thin at a Body Mass Index (BMI) of 21). While the heavier body weights would increase the energy cost of activities that involve movement of body mass (and hence energy requirement for equivalent activity patterns), the tissue constitutes an energy reserve that could attenuate the effect of low energy intakes during pregnancy and lactation.

Pregnancy. There is no evidence that women's intakes were improved in any way because they were pregnant. Energy intake per kg body weight fell as pregnancy advanced because total intake was unchanged while weight increased. For Kenya pregnant women, intake was 25-30 kcal per kg; it was 29-33 kcal per kg in Egypt and 41-44 kcal per kg in Mexico.

Not only was energy intake not increased during pregnancy, the amount of energy available for activity was actually decreased due to the rise in resting metabolic rate. The available energy (AE = energy intake minus resting metabolic rate) was of the order of 1000 kcal per day in Mexico in both trimesters two and three; AE was about 600 kcal per day in Egypt in trimester two and about 400 kcal per day in trimester three;[1] in Kenya, AE was about 300 kcal per day in the second trimester and essentially nil in the third. As noted earlier, there was evidence of a compensatory reduction in activity in Kenya pregnant women, but, unless there were additional undetected changes in activity, the amount of energy saved (approximately 100 kcal per day) would not have been nearly enough to reach the AE level even of Egypt women. Smaller weight gain would be the expected outcome of such energy limitation, and this was observed.

Kenya women gained 6.4 kg during pregnancy, about 15% less than was gained by Egypt and Mexico women. Women gained little or no weight in the first trimester of pregnancy (some lost weight) in Mexico and Kenya (data for Egypt were not reported). During the second and third trimesters, Egypt women gained 7.4 kg (equally deposited in trimester two and three); Mexico women also gained 7.4 kg (4.5 kg in trimester 2 and 2.9 kg in trimester 3); and Kenya women gained 6.4 kg (equally in the two trimesters). The 1.0 kg difference in gain between Kenya and the other two projects, if it were all adipose tissue, would represent an additional storage of about 40-50 kcal per day in Mexico and Egypt women.

The occurrence of the drought in Kenya adds variability to the data. To look at this question, the pregnancy sample was divided into four cohorts according to birth date (Table 16). The food scarcity period would have overlapped with the third trimester of pregnancy and some or all of the lactation period in cohort #1. In cohort #2, the third trimester of pregnancy and the first three months of lactation coincided with the food scarcity period. In cohort #3, both trimesters of pregnancy fell within the food shortage period but none of the lactation period did. The last cohort would have been in the first trimester of pregnancy during the drought and some might have overlapped into the second trimester but none beyond that point. Mean energy intake (averaged over all cohorts) during periods when generally unaffected and affected by the drought were, respectively, as follows: second trimester pregnancy, 1594, 1497; third trimester pregnancy, 1503, 1318; lactation 1-3 months, 2025, 1564; and lactation 4-6 months, 1846, 1590. The difference was small in the second trimester (100 kcal/day), larger in the third trimester (200 kcal/day) and very substantial during lactation (250-450 kcal/day).

[1]Calculations based on the assumption that RMR of Egypt women was the same as reported for Mexico.

TABLE 14

Maternal Height and Weight During Pregnancy and Lactation
[Mean ± SD (N)]

Parameter	Egypt	Kenya	Mexico
Height, cm	155.4±5.3(117)	154.3±5.7(90)	152.5±5.0(130)
Weight, kg			
Prepregnancy		50.7±7.6(90)	54.4±7.2(45)
Trim1 or 3rd mo	61.6±10.4(96)	50.5±7.7(90)	54.5±7.2(29)
Trim2 or 6th mo	63.2±9.8(63)	52.6±7.1(111)	59.0±7.0(68)
Trim3 or 9th mo	67.9±10.1(88)	55.6±6.9(121)	62.0±8.2(88)
Post-partum		51.6±6.4(115)	
Lactation			
mo 1	63.7±10.8(61)	51.6±6.5(123)	57.1±7.6(111)
mo 3	61.3±10.1(61)	51.2±6.9(98)	57.3±8.0(115)
mo 6	63.5±11.9(73)	50.7±7.4(105)	56.4±8.6(116)
Weight change, kg			
Pregnancy			
Trim 1			0.18±2.1(18)
Trim 2	3.7±2.9(45)		4.48+2.6(20)
Trim 3	3.7±2.5(46)	3.1±1.8(111)	2.86±1.8(52)
2 & 3	7.4±3.9(73)	6.3±3.4(111)	
1 - 3		6.4±3.4(61)	7.66±3.8(34)
Lactation			
0-2 mo		-0.9	
1-3 mo	0.27±2.1(30)		-0.04±2.2(99)
3-6 mo	0.01±3.0(40)		-0.71±1.9(105)
1-6 mo	0.18±3.5(38)		-0.92±3.4(99)
Body Mass Index[a]			
Pregnant			
3rd mo	25.6±4.1(95)	21.2±2.6(90)	[23]
9th mo		23.5±2.5(121)	
Lactating			
6th mo	26.1±4.8(70)	[21]	[24]

[a]Wt (kg)/Ht (m)^2. Figures in brackets calculated from mean ht and mean wt in table.

TABLE 15

Nutrient Intake of Pregnant and Lactating Women
[Mean ± SD (N)]

	Egypt	Kenya	Mexico
Energy Intake, kcal/day			
Pregnancy			
Trim 2	2100±492(66)	463±464(97)	2407±584(19)
Trim 3	1996±456(78)	1364±493(123)	2508±606(40)
Lactation			
1-3 mo	2249±423(83)	1822±623(122)	2628±580(55)
4-6 mo	2194±429(93)	1771±453(123)	2692±648(63)
Protein Intake, g/day			
Pregnancy			
Trim 2	68±18	41±14	67±17
Trim 3	63±16	38±16	75±20
Lactation			
1-3 mo	73±16	53±19	73±16
4-6 mo	70±16	54±17	77±20
Animal Protein Intake, g/day			
Pregnancy			
Trim 2	24±14	3.7±4.5	13±11
Trim 3	21±11	3.5±4.0	17±13
Lactation			
1-3 mo	26±15	4.3±4.6	13±10
4-6 mo	22±11	3.5±3.7	14±12

The quality of the diet during pregnancy also was different across projects (Table 15). The proportion of energy derived from protein was similar in the three projects (11-13%); energy derived from fat was low in Kenya and Mexico (13-14%) and moderate in Egypt (24%). Pregnant women in Mexico had three to four times as much animal protein as in Kenya; in Egypt, the animal protein intake was six times as much as in Kenya. None of the animal protein intakes would be regarded as generous by Western standards. Protective nutrients supplied by this class of foods (B vitamins, available iron and other minerals) would be at some risk depending on the quality of other items of the diet. Women in Mexico continued to consume pulque during pregnancy which is unlikely to have been entirely beneficial.[1]

The prevalence of anemia (as categorized by low hemoglobin levels) rose from 15% of Egypt women in the first trimester to 26% in the second and third trimesters. Macrocytosis, characteristic of folacin deficiency, was found in 6-8% of Kenya women among the 48% who were anemic. In Mexico, about 20% of pregnant women were anemic.

[1]Pulque does contribute a significant amount of some vitamins and minerals. In one liter (430 kcal): vitamin C, 60 mg; niacin, 4 mg; iron, 7 mg; and calcium, 120 mg.

The morbidity picture during pregnancy looked like that for the communities described previously. Women in Kenya had a high incidence of minor complaints -- upper respiratory illness, backache, headache, etc -- and about 4% had malaria. Pregnant women in Egypt were reported ill 4% of the time, most frequently with upper respiratory episodes; more than half of those illnesses were severe. Morbidity incidence was low in Mexico but many (10-12%) had bacteria present in the urine. All shared in the prevailing intestinal parasitism. The occurrence of significant illness in the second trimester had an adverse effect on pregnancy weight gain in Kenya as did the presence of vomiting and other complications in Mexico. Morbidity was unrelated to maternal gain in Egypt.

Maternal weight gain was related to energy intake in the third trimester in Mexico and Kenya (and to fat intake in Kenya), but not in Egypt. In all cases, pregnancy weight gain was negatively correlated with nonpregnant weight and BMI, that is, women who initially were heavier and fatter gained less weight during pregnancy, but the relationship was not significant in Kenya.

The Newborn.

Despite the major differences between projects in maternal characteristics and food intake, mean birth weight of infants was remarkably similar (see Table 5). Birth weight was somewhat higher in Egypt than in Kenya and Mexico (which were almost identical) and quite close to the reference population. There was no significant difference in birth weights between drought-period cohorts in Kenya. There are more boys than girls in all three project data sets; boys make up 57% of the sample in Egypt, 52% in Kenya and 60% in Mexico. Boys were, as expected, somewhat heavier than girls at birth.

The international definition of low birth weight is 2500 g or less which is approximately the third centile of the reference population; babies classed as low birth weight are at very high risk. In Egypt, 4% of newborns weighed less than 2501 g, in Mexico, 7% and in Kenya, 11%. Infants who died in the perinatal period were mainly in the low weight class. Thus, the lower range of birthweights is, inevitably, underrepresented in the longitudinal data set.

The Egypt project looked for factors that differentiated between the few babies of low birthweight and the others. Mothers of low birthweight babies were younger (five years), weighed less (10 kg) and gained less during pregnancy (4.8 versus 8.1 kg). There were no significant differences in maternal food intake, household SES or sanitation indexes. The other projects have not yet reported their data in this way.

All projects confirmed an expected association between maternal nonpregnant weight and weight at delivery with infant birthweight. Body fatness at pregnancy term, as indicated by BMI, is equally strongly correlated with birthweight in Kenya and Mexico and just misses significance in Egypt ($p=0.09$). Pregnancy weight gain is almost significantly correlated with birthweight in Kenya and Mexico ($p=0.06$) but not in Egypt.

Only in Kenya was maternal diet correlated with birthweight. There, intake of protein in the second trimester was a significantly positive factor and intake of energy and fat approached positive significance.

TABLE 16

Nutrient Intakes of Pregnant and Lactating Women According to Coincident Food Scarcity in Kenya (Longitudinal Sample)

Intakes/day	Energy kcal	Protein g	Anim Prot g	Fat g	Iron mg
Cohort 1: Birthdates May-August, 1984 n=20					
Preg Trim 2	1601	43	2.8	23	13
Preg Trim 3*	1351	35	3.3	19	11
Lact 1-3 mo*	1533	39	2.9	21	12
Lact 4-6 mo*	1590	52	3.6	22	16
Cohort 2: Birthdates September-November, 1984 n=35					
Preg Trim 2	1590	43	4.1	26	14
Preg Trim 3*	1306	34	3.8	19	11
Lact 1-3 mo*	1582	49	3.6	24	15
Lact 4-6 mo	1835	56	5.0	28	16
Cohort 3: Birthdates December, 1984-February, 1985 n=23					
Preg Trim 2*	1473	40	2.6	22	12
Preg Trim 3*	1306	38	2.1	17	12
Lact 1-3 mo	2057	62	3.5	30	18
Lact 4-6 mo	1756	54	3.1	26	17
Cohort 4: Birthdates March-June, 1985 n=15					
Preg Trim 2*	1534	46	4.5	23	14
Preg Trim 3	1503	46	5.8	24	12
Lact 1-3 mo	1976	58	4.1	30	18
Lact 4-6 mo	2010	65	2.1	27	20

* Period that coincided with drought-associated food scarcity. The impact in cohort #4 would have been chiefly in the first trimester of pregnancy.

Projects have examined other factors related to birthweight in their own settings; the findings are inconsistent. Maternal serious illness was a negative factor in Kenya but not in Egypt. SES was not related to birthweight in Kenya and Egypt but it was a factor in Mexico. Multiple regression models account for only 20-28% of variance in birthweight in any individual project.

Finding out what affects birthweight is of great importance. Birthweight is the most significant predictor of neonatal mortality. Mental function, as indicated by the Brazelton Assessment, is related to size at birth. Furthermore, in all three projects, birthweight is strongly correlated with infant weight in the four-to-six month age period. The effect of birthweight on subsequent size persisted through the sixth month in Mexico and Kenya but not in Egypt.

Lactation.

Food intake was increased during the first six months of lactation in all projects, but to varying degrees. There was, in all projects, a strong correlation between intake in the third trimester of pregnancy and in lactation; women who had more generous intakes during pregnancy also tended to eat more when lactating. On the average, Egypt women increased their intake by about 170 kcal per day, Mexico women by about 200 kcal per day, and Kenya women by 400 kcal per day. (See Table 15. The increase is compared to pregnancy intakes, but as mentioned above, there is a negligible increase during pregnancy when compared to non-pregnant, non-lactating intakes.) These increases are far below the published energy requirements of reference infants.[1] Requirement during the first month of life is 124 kcal per kg., or over 400 kcal per day for infants of CRSP observed body weights. Predicted requirements would increase to about 600 kcal per day by three months of age and about 650 kcal per day by six months. Had these children achieved reference growth, the requirement would be even higher, about 700 kcal per day by six montns of age. The energy cost of producing the milk would add another 100 to 150 kcal per day to the maternal requirements.

Lactational intake patterns appear stable over time in each culture, without the expected increases as the infant grows. Mean intakes did not change significantly over the six months of lactation in any of the locations. In Mexico, where women were followed during the seventh and eighth months of lactation, intakes increased by only 140 kcal per day over the previous period of lactation. A significant number of Egypt mothers were breast-feeding toddlers aged 18 to 24 months, but their intakes were less than 200 kcal per day greater than mothers of toddlers who were not breastfeeding (2379 vs. 2186 kcal per day).

The deficit between maternal energy intake and lactational needs can be met by use of body fat reserves and/or by decreasing physical activity. Kenya women lost 0.9 kg body weight in the first two months of lactation (Table 14), which, if it were all fat, would have yielded 135 kcal per day. This would have been enough to support lactational needs during that period. Mexico women lost 0.9 kg in six months, with a maximum yield of 45 kcal per day which would not have raised the energy available for lactation to reference level. Egypt women, on average, gained a little weight during that period. There is no information on activity that can be used to determine if there was a compensatory decrease in physical activity during lactation in any project. It seems unlikely that sufficient compensation could have occurred in Egypt; intakes coincide with only light activity in nonlactating women leaving little scope for savings of 500 to 600 kcal/day. This mechanism could have been brought into play in Mexico, where the usual activity pattern is moderate to heavy, but the cost in terms of activity foregone would have been consequential. The likelihood is that there was not sufficient energy to support full lactation anywhere and that the milk supply was below infant needs.

If intakes (plus any other adjustment) are inadequate to support lactation, then the infant must receive supplemental food or growth will falter. Even when maternal intakes are not limited by

---

1FAO/WHO/UNU. op cit. Table 21, p. 91.

access to food, evidence indicates that breast milk production is not sufficient to support reference growth rate beyond the third or fourth month of life. Continued steady growth or catch-up growth over most of the next few months is seen in developed countries if a supplement approaching the quality of breast milk is given.

Supplementary Infant Feeding.

Based on the CRSP evidence at hand, infants in Kenya would need supplementary feeding in the third month and infants in the other two projects from the beginning. Along with the potential benefit of additional nutrients, however, comes the risk of exposure to food-borne pathogenic organisms where sanitary practices are indifferent. To the extent that supplementary feeding displaces breast milk, there also would be loss of the protective immune substances present in breast milk.[1]

In Egypt, all infants received sugar-water throughout the first six months (a common mixture was a teaspoon of sugar in three to four ounces of water); one-third also were fed rice-water. The number of infants fed anything else rose from 8% in the first month to 27% in the third month and 46% by six months of age. Few infants received any foods that had essential nutrient value. Protein provided 6% or less of energy on the average.

Supplementary feeding of cereal gruels, cow's milk and thin soups was begun by Kenya mothers when infants were one to three months of age. The group average nonbreast milk energy intake (averaged across infants who did and did not receive supplements) was about 100 kcal per day over the six-month period (range 1-1051 kcal), with 10% coming from protein. About 40% of the protein was from animal sources, much more than was present in the family diet. Women whose food intake was low and those who gained little weight during pregnancy were most likely to use supplementary foods. This suggests that women who had stored fat during pregnancy or who had more generous intakes during lactation were better able to nurse their infants. Women who had serious illnesses were less likely to give supplementary food; the project believes this is so because of the extra effort involved in such feeding.

In Mexico, supplementary foods were introduced gradually and mostly after three months of age. Sweetened herbal teas were often the only food given in the first few months. Sugar provided 12% of the supplementary food energy and 18% came from dairy products. The amount of supplementary food in Mexico resembled that in Kenya.

In Kenya, infant supplementation was associated with some restoration of maternal fat, a benefit to the mother in view of the relative thinness of Kenya women, and perhaps critical to maternal wellbeing in a setting where women bear many children and food intake is low. Supplemental food intake of Kenya infants was positively correlated with infant weight during the first six months as would be expected with a supplement of good quality, and if lactation were insufficient for infant needs. In Egypt, the supplement, being of poor quality, might have adversely affected the ratio of essential nutrients to energy and increased the infant's risk of vitamin and/or mineral deficiencies. Weights of Egypt infants who were supplemented during the first 3 months were significantly less than those who were not supplemented, and there was a tendency for illness to be greater in the supplemented group ($p<.10$). The Mexico project has not reported on relationships between infant parameters and supplementation. Herbal tea with sugar is not likely to have benefited Mexico infants, but at least the water would have been boiled to make tea, which is not necessarily the case when sugar is given with plain water as in Egypt. A future search, tying records of household water sources and practices, to infant dosage with sugar water should reveal whether or not this is a factor in the high incidence of diarrhea observed in Egypt infants.

---

[1]Only Kenya project has reported on immune substances in milk (and only about a third of samples have been analyzed to date); the content was quite variable with some showing very high values. Relationship to maternal and infant variables has not been examined.

Infant growth.

Rates of growth have not yet been studied across projects but some of the factors that relate to achieved size at three and six months of age are known. One of these is birthweight, as noted above. The maternal pregnancy factors that related to birthweight remain significant predictors of infant size in Kenya and Mexico through the first six months of life. The mother's prepregnancy weight, weight at delivery, height and fatness (BMI) are correlated with both achieved weight and length of infants at three and six months. In Kenya, another factor, the amount of weight gained in pregnancy, is correlated with infant weight at three months but the effect has dropped out by six months. None of these maternal characteristics relate to achieved size of Egypt infants at three or six months.

Some maternal dietary factors also relate to infant size. As in other outcomes discussed previously, relationships are sparse in the Egypt data set. Only maternal protein and fat intake in the second trimester of pregnancy have any relationship to Egypt infant size, and that is only length, not weight, at three months. In Mexico, second trimester intake of animal protein correlates with infant weight at both three and six months. Food intake is more significant in Kenya. Intakes of energy, fat and protein during both the second and third trimesters relate to both length and weight of Kenya infants at both three and six months.

Maternal intake of energy, fat and animal protein during the first three months of lactation relates to weight, and even more strongly to length of infants at three months of age in Kenya. These same intake factors correlate with BMI of Egypt infants at three months of age. No maternal lactational dietary factors are positively associated with infant size at three months in Mexico, or with infant size at six months in any project.

Other factors than maternal intake must determine infant growth after the first three months. One factor is the amount and kind of infant diet supplementation. Morbidity experience seems a likely candidate but this has not yet been examined across projects. According to the Egypt project, the percentage of time an infant was ill with diarrhea was the best additional predictor of infant weight at six months, and household SES was next best. In Kenya, correlations between various aspects of morbidity and growth rate or size were weak; malaria and fever were associated with poor linear growth and fever with weight deficit. The strongest and most consistent correlates of infant weight in Mexico were internal and external sanitation of the household; infant illness was not associated with body size, nor was illness correlated with sanitation indexes.

Conclusions.

Women in the three projects made no dietary concession to pregnancy. By conventional standards, intake was notably low in Kenya and low in Egypt as well. Pregnancy weight gain was low in all projects and lower in Kenya than in Egypt and Mexico. Weight gain was related to food intake late in pregnancy in Kenya and Mexico, but not in Egypt. These findings are consistent with an assumption that food intake is quantitatively limiting in Kenya. It seems that women in all projects either do not know they should, or do not choose to, gain more weight during pregnancy, or there is some unrecognized, probably biological, factor that is regulating gain.

Women do eat more during lactation but only in Kenya during the non-drought period was the increment sufficient to meet lactational needs even in the first two months. Lactation was probably not sufficient to allow expected infant growth and supplementary feeding was not sufficient in quantity and/or quality to make up the deficit. These findings help to explain why infant growth is below reference standards, even in Egypt where the population as a whole appears to enjoy a reasonable diet.

Birthweight has important developmental and functional correlates. It is related strongly to maternal size and to some maternal dietary attributes, particularly in Kenya. Pregnancy and lactational influences persist through the first six months in Kenya, and to a lesser extent in Mexico, but have little continued impact on Egypt infants. Morbidity is a significant factor affecting

growth in Egypt but much less so in Kenya and not at all in Mexico. Much CRSP data remains to be evaluated before a clear answer to growth failure can be found.

OVERALL CONCLUSIONS AND THEIR IMPLICATIONS

The three study populations differed in important ways, both intended and unintended, but they shared one attribute in common: diminished stature. In these environments, the size a person was destined to be was determined early. Infants started life close to the size of the reference US population, but a lag in growth was evident by the third or fourth month. Stunting was established in the first year. After that, the growth rate was relatively "normal"; that is, the growth trajectory fitted the pattern expected for the shorter segment of American children. There was little evidence of catch-up growth; adults were shorter than they could have been in other circumstances. The population averages mask substantial variability, of course, and it is this that ultimately may allow identification of factors that associate with growth.

One might well ask why there is concern about early growth if growth rate is relatively normal after 12 months, albeit with a lower starting size at 12 months. The answer has to lie in the fact that within the CRSP data sets, and as reported in the general literature[1], there are numerous associations between achieved size and measures of human functional capacity and performance. In all three CRSP projects, body size characteristics of infants and toddlers correlated with measures of mental development; bigger children scored better. Smaller children were more prone to illness in Kenya and in Egypt, diarrheal episodes were more likely to progress in severity in children who were small. Small mothers produced small babies. There is at least a reasonable supposition that many of these are associates of the situation that produced growth failure rather than consequences of body size itself. Further analyses of the CRSP data sets can, in all likelihood, better establish the nature of the associates of growth failure and their causative role; at minimum, such analyses can help to define more closely the "households at risk". Cross-project comparisons already support justifiable speculation as to causality and, following from it, the implications of CRSP research findings for policy- and program-making in Egypt, Kenya and Mexico.

On the evidence of recorded low energy intakes of all target groups and general thinness of the Kenya project population, we conclude that food availability and energy intake were limiting in Kenya. Using the same criteria, this appears not to have been the case in the Mexico and Egypt projects. (That is not to say that all individuals ate enough in Mexico and Egypt, but food shortage was not characteristic of these populations.) It follows, as the results have shown, that associations with energy intake would be most readily detectable in the Kenya data set.

In Kenya, we looked for and did not find evidence of a metabolic adaptation to chronic food restriction, even during the time food intake was reduced due to scarcity. Thus, there does not appear to be a "cost-free" adaptation, that is, one that does not have impact on people's lives. When food was especially scarce, adults lost some weight, but indications are that activity was reduced in compensation for dietary energy deficit.

Infants as a group may have been food-deprived in all three locations. While there is no direct evidence of lactational failure, the indirect evidence is persuasive. Women's food intake did not increase during pregnancy and they gained much less weight during pregnancy than is customary in more privileged populations (about 7 kg vs. 12 kg). While their infants were somewhat lighter than reference populations, the difference in pregnancy gain mainly reflects a deficit of maternal tissue reserves that otherwise could

---

[1]See for examples: Calloway, D.H. The Functional Consequences of Malnutrition. Rev. Infect. Dis. 1982:4(4) and McGuire, J.S. and J.E. Austin. Beyond Survival: Children's Growth for National Development, UNICEF, New York. 1987.

be drawn upon to support lactation. Women increased their energy intake during lactation, but not by enough to provide the amount of breast milk needed for adequate infant growth. In Mexico and Egypt, the additional intake was, on average, less than half the amount needed as breast milk, without considering the energy cost of milk formation. Kenya women ate more during lactation when food was available; at best, intake was raised nearly enough for early lactation, and not sufficient for adequate lactation beyond the first two months. Sustained infant growth would depend on early and nutritionally adequate supplementation. This was not provided in sufficient quantity anywhere and the quality was especially poor in Egypt.

We are persuaded that inadequate lactation was an important cause of early growth retardation in all projects, but the situation is complex in Egypt. The preceding paragraph presented the case for lactational failure as being due to inadequate maternal intake and tissue reserves. Women in Egypt had more body fat than the others and, on average, they gained a small amount of weight during the first six months postpartum when they could have drawn on body tissue to support lactation. This suggests that lactation was diminished because infant demand for breast milk was reduced. Two factors could have affected demand -- early supplementation and morbidity. Virtually from birth, all Egypt infants received sugar-water of unknown sterility and many also were given other sugary concoctions and rice water. These items provide energy but no essential nutrients. The consequent dilution of the quality of intake could limit growth while providing energy and suppressing appetite. Both incidence and severity of illness also were high among Egypt infants. Infants who were ill and whose growth was slowed are likely to have had reduced food demand, so the stimulus to lactation might have been diminished.

A second puzzle is why children did not catch up in growth at later ages, when they had access to family food. There was, in fact, marginal improvement in relative standing between toddler and schooler ages but no evidence of change thereafter (i.e. adult heights were in line with children's). Short-term effects on growth become increasingly difficult to detect with advancing age because growth rate normally is slowed. Cross-project analysis revealed no strong or consistent effect of diet on the toddlers' rates of growth. Where multivariate analysis indicated some dietary influences, effects were more consistently related to height than weight and were associated with amount or proportion of fat and animal source protein or calories in the toddler diet. The proportion of these components in the maternal diet, an indicator of the household food supply, was significantly related to attained height and weight of both toddlers and schoolers in Kenya and Mexico, but not in Egypt.

Projects have reported some relationships between morbidity and toddler growth but these are neither striking nor consistent. Diarrhea had an adverse effect on the rate of weight gain in Mexico toddlers, but morbidity did not account for the unevenness of growth among the Egypt toddlers, where disease was most severe. Illness was shown to depress food intake of Kenya toddlers and probably affected the others as well. Thus, there is an inescapable circularity in attempting to assign causality either to illness or food intake. Morbidity was more often associated with size per se than with growth, with smaller and thinner toddlers being at higher risk of serious illness. Once a child is small, however she or he arrived at that state, the reserve capacity to deal with repeated significant illness was diminished.

The search for food effects on the selected outcome variables is complicated because of the strongly interrelated nature of the variables of interest and by the fact that an individual's food intake is more uneven from day to day than is the intake of the members of a like group on a given day. There may be real relationships that cannot be proved statistically. Despite this difficulty, it was shown that intake did affect functions of interest and certain behaviors that contribute to satisfactory outcomes. A most dramatic demonstration was the nearly doubling of episodes of illness during the period of food scarcity in Kenya. Kenya household sanitation score was higher where women had more to eat; when activity was reduced to compensate for the increased demand of pregnancy,

it was the household care-giving tasks that were omitted. Toddlers everywhere were more vocal and/or active if they ate more. Women's intake during pregnancy affected their weight gain and intake effects carried over into early infant growth in Kenya and Mexico.

There is evidence that the nutritional quality of diets consumed by segments of all three populations is substandard. No cross-project analysis of vitamin and mineral intakes has been undertaken. Each project has, however, shown that essential nutrients are at risk based on biochemical evidence (vitamin B-6 in Egypt, vitamin B-12 in Mexico) or clinical signs (B-complex vitamins in Kenya). The diet quality markers that emerge frequently, if not strongly, among the few so far examined are fat and foods of animal origin. These associations are likely to be indirect. Both fats and foods of animal origin would improve the energy density of the diets, perhaps making it possible for children to obtain more calories in a tolerable volume. Both factors would also improve the palatability and variety of the diet, possibly stimulating consumption of total food. Animal source foods could exert an effect in a more specific way, by providing essential nutrients otherwise low in the diet. The probability is low that the effect is due specifically to protein (or amino acids) because total protein intake was well above accepted standards. The search for effector nutrients would be aided by improved knowledge of the composition of foods consumed, but further analyses, even with the information at hand, should provide a sound base for intervention research.

The quality of CRSP diets, as measured by the abundance of fat and animal source protein, is positively related to the economic and social status (SES) of households. Households of higher SES are also more hygienic and are headed by more educated and/or literate adults. A major biologic reason that growth, health and development are related to SES -- a widely observed phenomenon -- is that economic sufficiency allows provision of enough nourishing food and social awareness informs the decision-maker about management of the household.

The principal decision-maker as to infant and toddler feeding and care is usually the mother. A mother generally acts in the infant's best interest as she sees it. In Egypt, where enough food is available and governmental intervention attenuates economic effects, one answer to early growth failure is likely to lie in the education of women. The situation of women was not ideal anywhere -- Mexico project refers to the restriction of information to women, beyond formal education concerns, and many Kenya women had minimal literacy skills -- but Egypt stands out: almost all Egypt women were deprived of schooling and only some ten percent could read and write.

The most consistent predictor of children's sizes, across all ages and the three projects, is the size of parents, particularly the mother. Whatever factors constrained parental growth are persistent in these cultures. CRSP findings show the special importance of total food intake at the beginning of life. Experimentation in animals indicates that it is necessary to feed a first generation to show reproductive improvement in a second. Size is of concern because it predicts the quality of function in important domains.

POSSIBILITIES FOR INTERVENTION

The implications of the CRSP findings are clear. As the three populations arrived at similar ends by somewhat divergent routes, points of intervention are not necessarily the same.

In Kenya, there is a need to assure a stable and adequate food supply. The evidence indicates that even provision of more of the same diet would have some benefit. Broadly based development effort is probably the best approach. More local initiatives might include small irrigation projects and support of small ruminants and poultry projects.

During the study period, the Embu district experienced food scarcity associated with drought, the effects of which were ameliorated by the active intervention of the Kenya government and the CRSP field staff. Children failed to grow at the projected rate and adults lost weight which was regained when the food supply improved, a pattern observed seasonally throughout much of Africa as the norm. The CRSP was uniquely positioned to document what transpired within the community. Kenya project findings provide information on family coping strategies some of which were helpful in the short term but counterproductive in the longer term (e.g. sale of livestock). A review of these records may suggest better ways in which communities could avert the consequences of periodic food shortage.

In Mexico, the total food energy supply appears to be adequate but food quality is less reliably assured. Preliminary evidence suggests that the situation would be improved by increasing the proportion of animal source foods as the only assured contributor of vitamin B-12 and a major contributor of other vitamins and trace minerals. Energy now derived from the alcoholic beverage pulque might well be displaced by more nutritious food with benefit to health.

In Egypt, both the amount and composition of the food supply seem to be adequate. Governmental subsidization of nutritious foods appears to be an effective measure even though not all individuals have a fully adequate diet. More attention needs to be given to maintenance of hygienic standards in the household and community.

In all three locations, programs addressed to pregnant and lactating women need to be introduced or strengthened. Research is needed to determine why women do not eat and gain enough in pregnancy; if there is a fear of inability to deliver a larger baby as some have suggested, then good obstetrical care needs to be assured. Women need to be encouraged to eat enough to promote the lactation needed to support good infant growth; they need to learn what constitutes safe and adequate supplementation of the infant diet. Unless and until women's dietary habits are changed substantially, it may be necessary to make suitable supplementary infant food available. In Kenya, it appears that suitable food is in more scarce supply than is information; the information deficit seems largest in Egypt.

Both men and women need to be better educated generally and certainly better informed about nutrition and health matters. Women are important decision-makers in many aspects of family welfare and their capacity to make these decisions must be strengthened. It would seem that the medium of television could deliver the message in Egypt and possibly Mexico. Radio is available in all three places. For the long term, classroom training in food selection and preparation, hygiene and health is in order.

Nutrition monitoring systems would be more effective if there were better information about the composition of foods as produced and consumed. As it now stands, intake levels of vitamins and minerals can only be approximated in Kenya and Egypt which adds to the difficulty of nutritional diagnosis. Governments should sponsor the needed analytical work; the capability of food analysis exists in all three countries.

EPILOGUE: STRENGTHENING INSTITUTIONS

The prospects for nutrition, including research, effective nutrition monitoring and intervention efforts, have been enhanced in Egypt, Kenya and Mexico. The results of the projects have been reported formally to government officials and policy-makers at conferences convened for the purpose in Kenya and Egypt; a conference will be held in Mexico in September, 1988. The conference format allowed for questioning and exploration of the significance of the findings locally and, by extension, to like situations elsewhere in the country. So far, it is the Ministries of Health that have taken greatest cognizance of the work. In Egypt, nutrition is a focus of the current five-year plan.

In the last year of the CRSP, each of the overseas Principal Investigators was asked to comment on the significance of the research collaboration to his institution and nation. Although institutional strengths differed in the three host countries initially, there was substantial agreement as to the most important legacies of the CRSP. These may be grouped as follows:

1. The CRSP data base. Each country has a clean data base containing all the CRSP files for its own study location as well as the other two sites.These can be used for both programmatic and training purposes. Importantly, the requirements for construction, maintenance and analysis of a large data set are known; the capability to meet these requirements is greatly improved. In all cases, a national food composition data base was augmented and converted to electronic form for ease in application.

2. The field site as a continuing training and research venue. Both Egypt and Kenya plan to continue work in the study communities as a means of training advanced students in field methodologies. Some of these students will undertake graduate research there. All three countries have follow-on research projects in progress. In Solis, Mexican collaborative research addresses "technology for the surviving child", including effects of vitamin A and carotene, and the US-Mexico cooperation continues with a study of the effects of zinc deficiency and supplementation. In Egypt, a model child-survival unit is being developed in Kalama, the Institute is following up anthropometry of infants and children in ex-CRSP households and the US-Egypt team continues research on vitamin B-6. In Embu, the US-Kenya collaboration involves additional study of ex-CRSP households: anthropometry and cognitive development of studied infants and toddlers and an applied nutrition program targetted to women and children under age 5.

3. The upgrading of research capability. All the collaborating institutions have received a contribution of research equipment. Laboratory equipment (for hematology, immunology and respiration-metabolism studies) has expanded or extended existing capabilities. The availability of microcomputers has allowed significant improvement in both research administration and field data management. Finally, better transport vehicles make field work feasible. As Dr. Chavez has said, in sum, the CRSP has enhanced the institutional capacity to apply "the latest advances in technology...to the study of human beings in their own communities."

More significantly, research teams were introduced to new ways of thinking about research. The fundamental training was in place in senior research colleagues,but local constraints had not often allowed them to use their capabilities to the fullest. Dr. Galal has commented on a widening of experience, introduction of disciplines not previously involved in work of the Nutrition Institute and a "transfer of knowledge and technology which benefitted several Egyptian institutions..." All projects provided opportunities for key staff to refresh and enhance their research capability, by exchange visits, seminars and meetings.

There was also a substantial formal training component in each country. Graduate students carried out Masters or Doctoral research as part of the field work in Egypt and Kenya. Two Kenyan staff are enrolled in graduate programs at UCLA and a Mexican investigator has completed doctoral training at the University of Connecticut. In addition, large cadres of junior field staff received training and experience by their employment in the local CRSP projects. Dr. Bwibo has noted that some have been admitted for advanced training on the strength of this experience and some are employed in continuation field work in Embu.

Dr. Phillip Payne, Chairman of the External Evaluation Panel, concluded his cover letter on the Third Report of the EEP with the following positive statement: "I really feel the [the CRSP has] already made a very great contribution to the building of institutions and people. Certainly, I count my two field site visits (Egypt and Kenya) as amongst the very

best experiences of the past year; we met some very fine young people who were seeing for the first time that the disciplines of research can be combined with a real commitment to a community."

4. The building of a transnational research network. Over the six-year life of the CRSP, lasting linkages were forged between the collaborating investigators both within and across projects. These linkages have resulted in the further research described above, in continued exploration of the CRSP findings and in joint publications. The network functions in less obvious ways as well -- in solicitation of advice and appointment to international committees and consultative groups, as examples. In a very real sense, USAID staff also are part of this network which has implications for future binational activities.

Although institution-building was a significant positive contribution of the CRSP, the process would have been smoother if more time and more travel funds had been allocated to allow earlier building of working relationships before the heavy demands of actual research were imposed on the collaborating institutions. Institutions felt pressed to accommodate the needs of more technologically advanced research than had been included in their programs in the past. The end result was satisfying, but the process might have been made less stressful.

Networking and institution- building have clearly been a two-way proposition. The US institutions have been enormously strengthened in their ability to conduct field research, several American graduate students have received degrees based on CRSP research participation, and there has been significant development of foreign language skills. Most of all, the participating investigators and the Berkeley management team have developed a deep appreciation of the problems confronted by people in poor communities and the difficulties under which scientific colleagues labor in less privileged places. As is so often the case, we feel we received far more than we gave.

APPENDIX A

BASIC VARIABLES[1] LIST (October, 1984)

Community description

Based on Phase I data collections. Reviewed and updated to reflect significant community changes at approximately one year intervals.

Climatic data	
Average rainfall	Monthly
Average noon temperature, or daily maximum and minimum	Monthly
Barometric pressure, each research site	Once only

Household data	
Household entry data	At entry
Household demography	At entry + 6 month updates
Household social and economic measures[2]	Twice
Disabilities and chronic illness in household	At entry + 3 month updates
Anthropometry (nontarget): Height	Once
Weight	Twice, by season[3]
Household food use	2 days/month
Household morbidity, 7-day recall	Weekly

Lead female (P=target pregnancy; L=target lactation; N=all others)	
Reproductive history	At entry
Physical assessment of nutrition and pregnancy related variables	N: every 6 mo; P: 5th,8th mo; L: 6 months
Pregnancy outcome	At delivery
Pregnancy/lactation survey	Monthly
Anthropometry: Weight	Monthly
Height (in duplicate)	Once when not pregnant
Food intake	2 days/month
Morbidity, 7-day recall	Weekly
Illness disability and task assignment subroutine[5]	As indicated
Resting metabolic rate	N: every 3 mo; P: 5th,8th mo; L: 1st,3rd & 6th months
Sanitation and child care activities[6]	Every 2 months
Blood analyses, albumin, hemoglobin	P: 8th month
Milk analyses	L: day 1-3, 1st, 3rd, 6th mo
Time allocation/activity pattern[7]	Monthly
Psychology[8]: Ravens Matrices	Once
WAIS (Subscales)	Once

Lead male	
Food intake: use of household food on same days as other individuals (not necessarily total intake)	2 days/month
Anthropometry: Weight	Monthly
Height (in duplicate)	Once
Morbidity, 7-day recall	Weekly
Resting metabolic rate	Every 3 months
Time allocation/activity pattern[7]	Monthly
Psychology[6]: Ravens Matrices	Once
WAIS (Subscales)	Once
Illness disability and task assignment subroutine[5]	As indicated
Infant (from target pregnancy)	
Food intake (if breast fed, quantitative estimate of supplementary food intake; otherwise estimate of total intake)	2 days/month
Anthropometry: length, weight, arm & head circum.	Monthly
Morbidity, 7-day recall	Weekly
Dubowitz Scale (first edition)	Within 3 days of birth
Physical assessment: birth condition	At birth
nutrition related variables	6 months
Psychology: Brazelton	1-7 days old
Bayley Motor Scale	6 months
Infant Behavior Record	6 months
Observation of caretaker and child	2, 4, 6 months
Target toddler - 18 to 30 months	
Food intake (by observation or combination of observation and reporting)	2 days/month
Anthropometry - length, weight, arm & head circum.	Monthly
Physical assessment of nutrition related variables	Every 6 months
Physical assessment of vision and hearing	Once
Morbidity, 7-day recall	Weekly
Illness subroutine[9]	As indicated
Psychology[8]: Bayley Mental Scale	18, 24, 30 months
Bayley Motor Scale	18, 24, 30 months
Bayley Infant Behavior Record	18, 24, 30 months
Observation of caretaker and child	18, 24, 30 months
Target schooler - 7 to 9 years	
Food intake	2 days/month
Anthropometry: Height, head circumference	Entry and exit
Weight, arm circumference	Every 3 months
Morbidity, 7-day recall	Weekly
School attendance (days present/days of school)	Monthly
Psychology[8]: WISC-R (Subscales)	Entry and exit
Ravens Matrices	Entry and exit
Barrett-Yarrow-Klein classroom observation	Twice during school year
Playground observation	Twice during school year
Physical assessment of vision and hearing	Once
Physical assessment of nutrition-related variables	Every 6 months

Explanatory notes

1 Minimal list of variables that will be collected by all projects and which, as a minimum, will be subjected to inter-project analyses.

2 Each project will report variables collected and will specify how these are to be weighted and combined to yield a classification of households on a Social Scale and on an Economic Scale appropriate to the community. The original variables will be stored centrally.

3 To correspond to seasons of "plenty" and "want" appropriate to each project; if deprivation is not seasonal, select two representative periods, e.g. dry season/wet season.

4 N, L: Monthly conception survey; P: Monthly pregnancy survey; L: Monthly lactation and infant-feeding survey.

5 Illness disability and task assignment subroutine (of lead male and lead female) - days 1, 3, 7, 14, 21 ... and weekly during illness; current and retrospective data concerning degree of disability in performance of normal tasks and identification of task assignments to others. For this purpose, illness is deemed to end when there has been no reported disability for three consecutive days.

6 Sanitation and child care activities (of lead females): These variables will be collected by all projects. Methodology is recognized to be project-specific. Each project will report variables collected and will specify how these are to be weighted and combined to yield scores for each component, i.e., a Child Care Score and a Sanitation Activities Score.

7 All projects have agreed to collect this information on a subsample in Year 2 of Phase II. Methods are recognized to be project-specific. Each project will identify and report the specific variables recorded as well as the method by which they are to be aggregated into composite descriptors. The subpopulation studied should be as representative of the total sample as is feasible.

8 Psychological tests: Individual projects may use culturally appropriate subscales and/or different numbers of components of the tests. The projects will report the actual variables recorded and the weighting factors and groupings to be used in deriving a composite rating/score.

9 Illness subroutine (of toddler): (for all illnesses detected as starting within 24 hours prior to weekly visit except: localized skin lesions, minor trauma, conjuctivitis, pains of less than 1 day duration, headache, upper respiratory infection without fever) Subroutine to include revisit days 1, 3, 7, 14, 21...and weekly until recovery, and record: state of illness (diagnosis and severity indicators); weight; semi-quantatitive one day intake (recall of past 24 hours) by report of care-giver; and qualitative activity index. Recovery is defined as three consecutive days without symptoms (2 recall + current observation).

10 Projects to select alternative measures for children who do not attend school, and advise Management Entity.

APPENDIX B

PARTITIONING OF VARIANCE IN DIETARY DATA

by

George Beaton and David Lein

In the original design phase of the Nutrition CRSP, the expectation was that relationships between food intake and other variables would be based on three month averages, perhaps moving averages. The necessity to pool data arose from the recognition that there is major day-to-day variation in intake within individuals. Most of the relationships that would be of interest were between intakes persisting over moderate periods of time, rather than on a single day, and an outcome variable. Based on limited data available in the literature at that time[1], the assumption was that energy intake might exhibit a within-person variability (SD) equivalent to about 25% of the mean intake. It was hoped that the sample selection would maintain a variability between people of at least that amount since the literature available suggests that in normal populations the within and between-person variances were about equal[2]. By pooling data over 3 months (6 measurements of intake), the within-person variance of three month mean would be about 10% for energy and the variance ratio ($SDwithin^2/SDbetween^2$) would be about 0.16. It was felt that this would be satisfactory for analyses, giving an acceptable level of attenuation of statistical relationships.

The following table presents the results of ANOVA runs (partitioning of variance between the subject or "model" effect and the residual error in a one-way ANOVA). Standard Deviations have been calculated without taking into account the unbalanced design.

---

[1]Beaton, G.H., et al. Sources of variance in 24-hour dietary recall data. Am. J. Clin. Nutr. 32:2546-2559. 1979.

[2]National Academy of Sciences. Nutrient Adequacy: Assessment Using Food Consumption Surveys. National Academy Press, Washington DC. 1986.

Measures of Variance in Intakes of Toddlers and Lead Females in Egypt, Kenya and Mexico.

	KENYA		EGYPT		MEXICO	
	Toddlers	LF	Toddlers	LF	Toddlers	LF
ENERGY (kcal)						
CVinter[a]	19	18	24	13	25	21
CVintra[a]	48	46	38	28	32	25
TOTAL PROTEIN (g)						
CVinter	20	20	26	13	22	20
CVintra	59	53	45	35	37	30
ANIMAL PROTEIN (g)						
CVinter	64	68	32	23	52	61
CVintra	166	204	83	89	85	100
FAT (g)						
CVinter	41	28	26	16	34	34
CVintra	68	61	59	51	51	47
VARIANCE RATIOS[b]						
Energy	6.1	6.4	2.5	4.9	1.7	1.5
Total protein	8.1	7.0	2.9	6.7	2.8	2.1
Animal protein	6.6	9.1	6.5	15.0	2.7	2.6
Fat	3.6	4.6	5.1	10.1	2.2	1.9

[a]CV=coefficient of variation (%)=(standard deviation / mean) x 100. 'Inter' is between individuals and 'Intra' is within individuals.

[b]Variance Ratio is the square of the standard deviation intra divided by the square of the standard deviation inter. The smaller the ratio, the greater the power to detect relationships with nutrient intakes.

Kenya

For toddlers, the data base for these analyses consisted of 2603 observations of one day food intakes of 109 toddlers each of whom contributed at least 12 observations between the ages of 17.0 and 32.0 months. The average number of observations per child was 23.9 with a range from 12 to 30. The selection coincides with the longitudinal sample and includes also specific rules for the correction of sex classification and exclusion of outliers.

It is readily apparent from the data in the table that there was substantially more within-person variance in the Kenya food intakes than had been expected in the original design. Expressed as the Coefficient of Variation (CV), the within-person variability for toddler energy intake was 48% while the between-

person variability was 19% (compare to design assumptions of 25% each). The result of these departures was a greatly increased variance ratio (6.1 compared to 1.0) and as discussed below, a greatly weakened statistical power. In the table, the variance ratios for all of the nutrients measured are presented. They are generally similar except for fat which has a substantially smaller ratio. The within-person variance has not been inflated because of progressive change in weight (and hence intake) across time; when intakes were expressed per kg imputed body weight, the variance ratios were similar to those of absolute intakes. For some nutrients, the analyses have been run for intakes expressed per 1000 kcal (a measure of "dietary quality"). The variance ratios tend to be higher. Part of the variance between subjects has been removed by controlling for total amount of food consumed and the variability in the nutrient density of foods from day to day is exposed. The effect is particularly striking for total protein.

Two other potential sources of the within-person variance were considered: that there was a marked difference in variability of intake attributable to household food shortages in the drought period, and that the intake methodology had the effect of attributing intake to the wrong day in a pair. As a first approach, scatter plots of data were visually examined. What was striking about these plots was not a marked change during the "famine" period but rather the very high variation throughout the whole period and even between adjacent days. Whatever is the source of the variance, it does not appear to be the food shortages and potential "feast and famine" situation of the drought period. More detailed studies, discussed in the Management Entity Report[3], demonstrated that the variance between adjacent days was comparable to the variance across non-adjacent days and that there was no systematic difference between the first day and the second day of adjacent pairs. It was very unlikely that intake was being attributed to the wrong day.

Lead females (n=214, mean observations per person = 24.6) selected were from households defined by ME as being in the longitudinal sample. The variance ratios observed tend to be slightly higher in women than was seen in toddlers. That for animal protein was much higher. In adult women, the variance ratio for fat was again lower than that for the other dietary variables.

Mexico

As was done for the Kenya project, Mexico data were selected from subjects included in the longitudinal data set (as defined by ME). Recognizing that the method change in Mexico had a marked effect upon mean intakes, only data collected after December 31, 1984 (i.e. with the final methodology) were examined. To be included in the data set, a particular toddler was required to contribute at least 8 observations within the time defined by the target window (18-30 months). This resulted in the creation of a data set comprising 947 observations from 50 toddlers with an average of 18.9 observations each.

The contrast of the variance ratios with those seen in the Kenya data sets is striking. It is noteworthy that the variance ratios are not particularly

---

[3]Management Entity Final Report, 1988.

different between total energy (or total protein) and animal source energy (or animal source protein). The fact that Mexico project analyses consistently demonstrated stronger relationships between these variables and outcome measures is not explicable as an artefact attributable to different relative error terms in the variables (as was implied might be a contributing factor in the fat intakes in Kenya). Conversely, what is striking is the sharp increase in the between subject variability in the animal source vectors (see CV's in the table). This would suggest that whatever use of animal source foods may mark (intake of one or more specific nutrients or characteristics of the household and associated factors), the relative range among individuals is appreciably greater for the animal source nutrients. This is what would appear to be driving the Mexico analyses. It will be important to explore this phenomenon further to determine what other variables associate with use of animal source foods. In such further analyses, or in any interpretations of the present analyses, note should be taken of the major skew that exists within the animal source vectors (the CV's approach 100%; clear evidence of a skew). The distributions were not normalized for these analyses.

It is to be noted that the relative variabilities and the variance ratios seen for total energy, total protein, and total fat in toddlers (and in adult females) are in keeping with the general expectations of the original design and with variabilities reported in industrialized countries. Comparative information for animal source energy and protein is not available.

As for toddlers, data for lead females were selected from the longitudinal sample and the longitudinal time windows as defined by ME. An outlier screen was applied and intake records with more than 5000 kcal/d were rejected from the analyses. It was required that subjects included contributed at least 8 intake records (the actual ranges were 8 to 32). No attempt was made to separate pregnant or lactating women from their nonpregnant, nonlactating compatriots. There is somewhat less variability in energy intake among women than was seen in toddlers (but note that toddler analyses were not controlled for age and neither were controlled for weight; these might contribute some variance). Again the variation between subjects and within subjects increased sharply with animal source foods.

Egypt

The Egypt project provided 2770 intake records for toddlers in the age range 18 to 30 months. To these records the following exclusion rules were applied: must be in the longitudinal data set, must have been weaned, intakes could not be in excess of 4500 kcal; after those exclusions, at least 8 records must be available. The resultant data set provided a total of 1392 records from 85 toddlers contributing 8 to 27 records (mean = 16.4). The between subject variances, expressed as CV's, are comparable to those seen in Mexican toddlers and close to design expectations. This is moderately surprising since it is known that the data set includes an observer effect that could be expected to increase the CVinter to some degree. The within-person variances are again comparable in range to those seen in Mexico and much lower than those seen in Kenya. However, the ratio of variances is generally higher for Egypt than for Mexico and that for animal protein is particularly surprising.

The partitioning of variance in adult females was examined for subjects in the longitudinal data set with at least 8 observations be contributed and reported energy intake not be greater than 5000 kcal. From an initial pool of 5505 observations, 3420 met these criteria. The analyzed data set comprised data from 152 adult women contributing an average of 22.5 observations. Adult women exhibit a lower between-person variation, relative to the mean, for most nutrient vectors than do the toddlers. The relative within-person variabilities also tend to be reduced (except for animal protein), but the variance ratios tend to be higher for adult women than for toddlers. These subjects depart quite appreciably from the original design assumptions, making it more difficult than anticipated to detect associations (the departure is not as severe as was seen in Kenya but more so than for Mexico).

Implications for interpretation of interproject comparisons

The predicted attenuation of bivariate correlation and regression coefficients, based on the observed variance ratios, may be calculated. Details of the calculation of these attenuation factors will be found in a report prepared by the Federation of American Societies for Experimental Biology[4]. Application of the factors may be illustrated by an example using the energy variance ratio from the Kenya project. If the true relationship between energy intake and a body weight parameter were described by a correlation coefficient of 0.4, with 2 days of data (1 month's observations), the observed correlation might be about 0.2. With 3 months of data (6 observations) it might rise to about 0.28, and if a six month mean were used it might be 0.32. If the original regression slope were 0.2, the observed slopes might be only 0.05, 0.10 and 0.13. Thus, both the estimate of the relationship and the power to detect it as statistically significant are sharply reduced by these high variance ratios. It implies also that the ability to detect relationships across short periods of time is seriously blunted. Some of the analyses presented by the Kenya project involve mean intakes over six month periods. Relationships were not seen when shorter intervals were used.

A very serious implication of these observations is the need to guard against the false negative interpretation of analyses. That is, if a relationship is not seen, it may be because it does not exist. It may also be because the attenuation is so great that it is not detected in conventional analyses.

A second problem is apparent from the analyses presented in the foregoing pages. The variance ratios, and hence degrees of attenuation of relationships, vary between nutrient vectors within projects and within nutrient vectors between projects. The implication is clear. If, within a project, the real biological relationships between several nutrient vectors and an outcome variable were comparable, the observed relationships would differ because of different degrees of attenuation. Analogously, between projects, different nutrient vectors may appear as significant predictors of outcomes as a result of differences in variance ratios as well as because of

---

[4]FASEB Life Sciences Research Office. Guidelines for Use of Dietary Data. Federation of American Societies for Experimental Biology. Bethesda, MD 1986.

true differences in the biological relationships. This may be a particular problem when simple correlation analyses are used in the selection of variables to be entered into regression models; the correlations would be attenuated as indicated above and this would influence the selection decision. Once entered into multivariate regressions, it is difficult to predict the effect of the variance ratios. The observation of different nutrient-function relationships across projects, or the presence of relationships in analyses for one project and absence in analyses for another must be interpreted with the variance ratios in mind.

Examining the variance ratios alone begs the question of why the variance ratios differ. Although the foregoing discussions have emphasized the variance ratios and the CV's in relation to original design targets, examination of the absolute variance components is of interest. The variance ratio involves both components. A question of interest is which differs between projects and why does it differ. Intraindividual variances would differ if there are real differences in the stability of eating patterns or if there were a random methodological error in recording intake that differed between projects. Interindividual variances would differ if indeed there were differences in the "homogeneity" of the populations studied or if there were systematic biases operating across individuals within one or more of the projects. It would appear that, for toddler intakes, between-subject variance differs between projects more than does the within-person variance (fat intake in Kenya does not fit this pattern). That is, the differences in variance ratios described above are less likely to reflect differing methodological errors across the projects than differences in the range of subjects themselves. Specifically, the Kenya subjects would appear to be much more homogeneous than either the Egypt or Mexico subjects. This conclusion must be tempered by the potential effect of interviewer biases on the between-subject variance. Nevertheless, the results do suggest again that the power to detect relationships between energy intake and outcome variables differs between projects. The differences between projects in the CVinter and CVintra of the nutrient vectors for adult females are not as consistent as would seem to the case for toddlers. One cannot suggest as easily that it is one component or the other that differs between projects. These similarities and differences between projects would be worthy of further exploration both as a basis for further understanding of the data and as an approach to "external validation" of the dietary methodologies.

Finally, as was noted above, examination of the standard deviations for a number of the nutrients suggests that the primary distributions carry major skewing. This is very apparent, for example, in the Mexico toddler animal source energy and protein but is seen also in a number of other nutrient estimates across projects. In the preliminary analyses reported by projects as well as those included in the present report, specific consideration has been given to the potential impact of such skewing of the dietary variables only in the case of the Mexico project. Here, as reported in the analysis of growth patterns, it was found that two individuals had very unusual intakes and also unusual weights and heights. Not only would these subjects have accounted for a major part of the skewing but also, in this case, unduly influenced the analyses. Further examination of the intake distributions in relationship to analytical questions is in order.

APPENDIX C

SAMPLE GROWTH PLOTS FOR EGYPT TODDLERS

by

David Lein and Steve Selvin

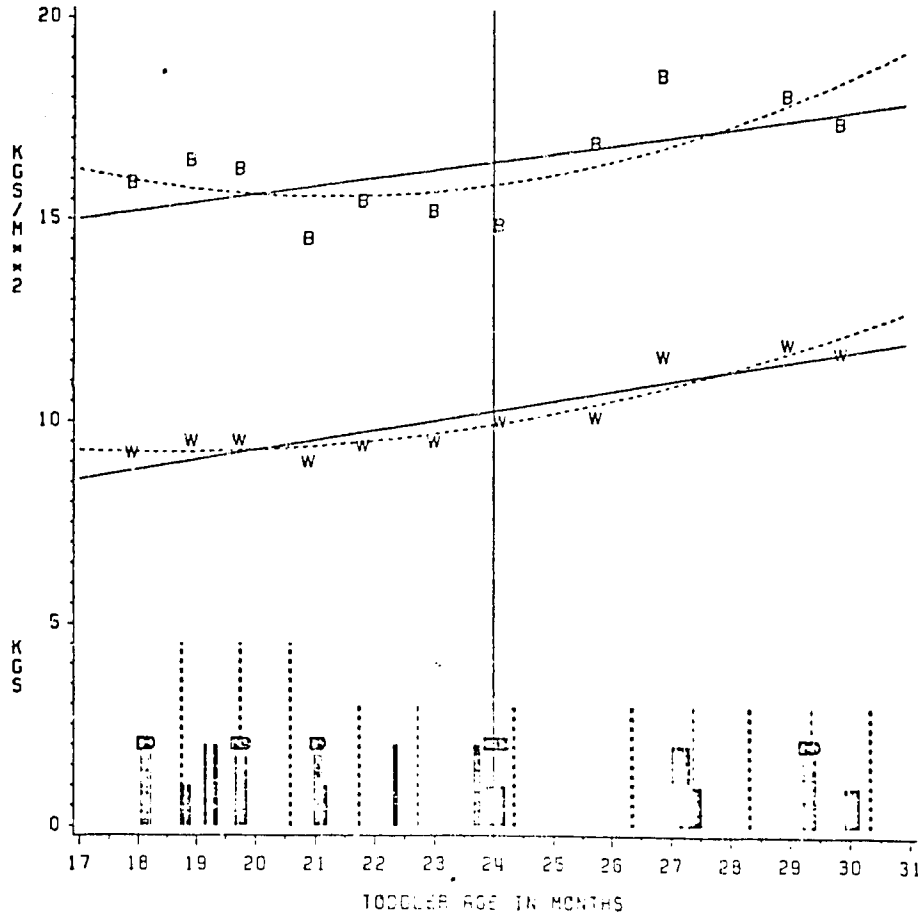
Following are four examples of growth plots for Egypt toddlers. Each graph shows weight gain over the 12 month period between 18 and 30 months of age (each measurement is represented by a W) and change in body mass index (height divided by weight squared) over the same period (each measurement is represented by a B). Both a linear and a quatratic equation have been derived for weight and body mass index, and are plotted on the graphs as a solid line and a dotted curve.

Several other measures are represented at the bottom of each graph. Food intake measures are shown as vertical dotted lines; since there were usually two consecutive days of intake measured, these appear as parallel dotted lines. Weaning dates can be determined by the height of the dotted line - the taller lines are for breast-fed days. For example, the first toddler shown below was weaned at about 21 months of age. The six preceding food intake measures (3 pairs of two days each) are represented by taller dotted lines than the remaining food intake measures. The second toddler was weaned prior to the study, and does not have any tall dotted lines.

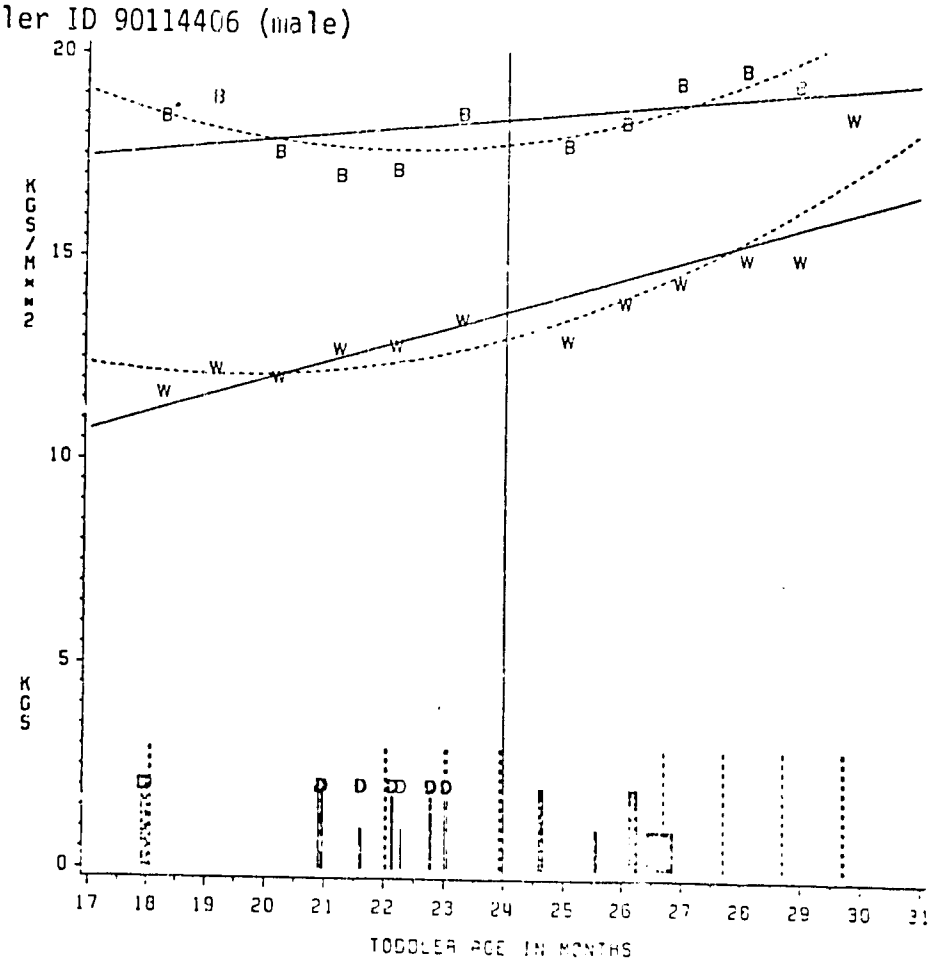
Also shown at the bottom of each graph are the illness days reported for the toddler. Each day of illness is represented by a solid vertical line. Thus illness episodes lasting several days are represented by a cluster of vertical lines. Illnesses categorized as severe by the field personnel are represented by a taller solid line than those categorized as mild. Illness episodes categorized as diarrhea have a D above the solid line. The first toddler below had several illness episodes, most of which were severe for at least part of the duration. Six of the episodes were for diarrheal disease.

Thus, it is possible to use these graphs to visualize the rate of growth in weight and the change in body mass index over the year. The deviations from linear growth can be seen easily. Simultaneously, the effect of weaning and of differing types and durations of illness on the growth pattern of an individual toddler can be examined.

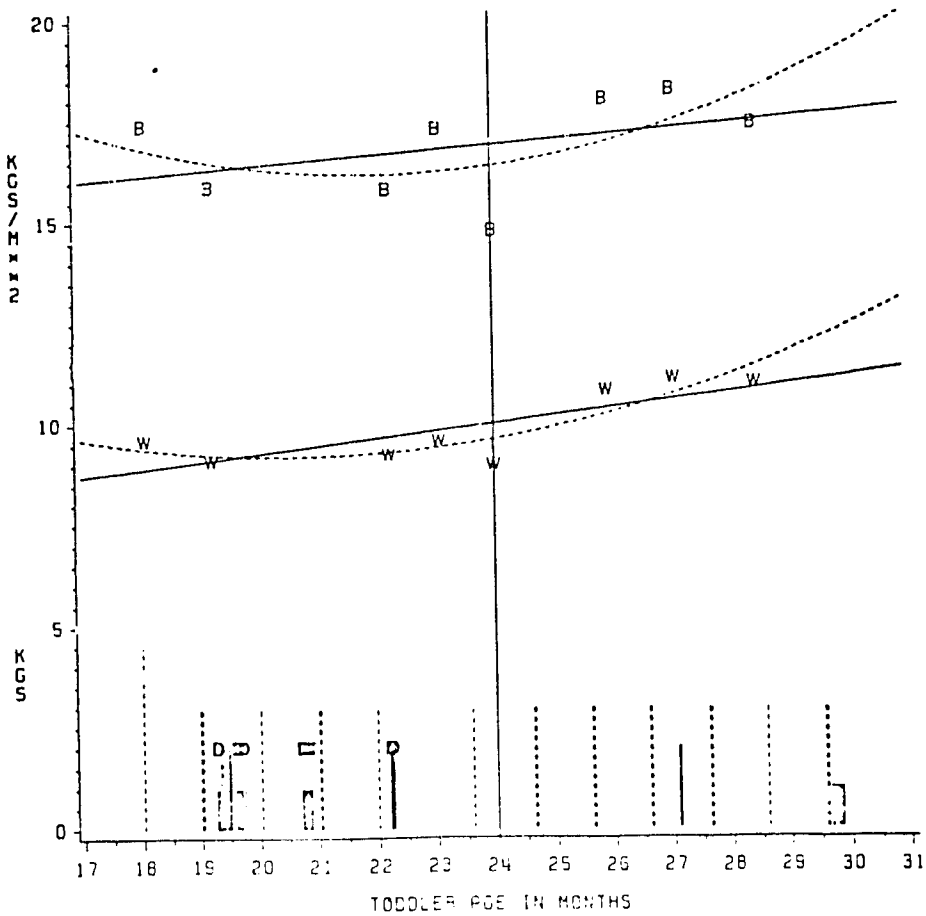
Toddler ID 10149407 (female)



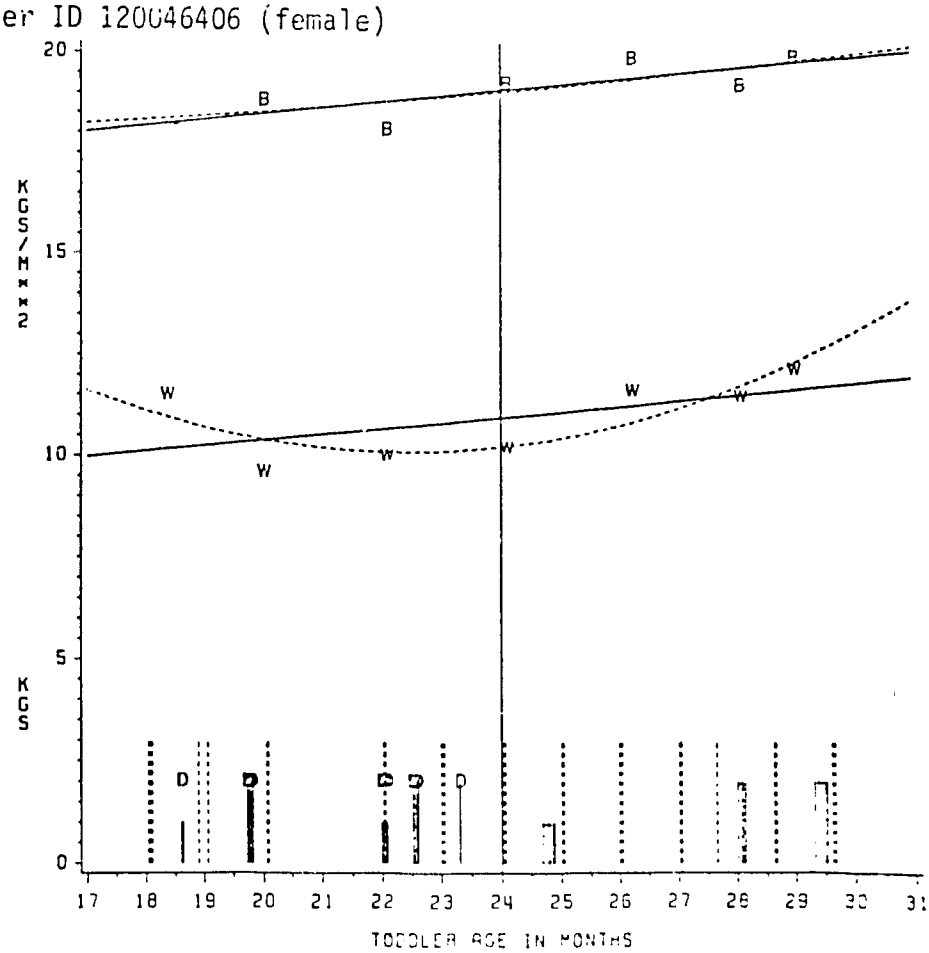
Toddler ID 90114406 (male)



Toddler ID 120051405 (male)



Toddler ID 120046406 (female)



APPENDIX D

EXAMINATION OF GROWTH PATTERNS IN EGYPT, KENYA AND MEXICO

by

George Beaton and George McCabe

For the analyses to be reported in this section, certain inclusion or exclusion rules were applied. All available data were eligible for inclusion and no attempt was made to define the relationship to longitudinal samples defined in project and management reports. Rather, where longitudinal data sets were needed, as in the generation of individual regression lines, criteria of minimum number of observations across minimal periods of time were established.

As an initial step all data for children to the age of 12 years were entered into the CDC program for calculation of Z scores and other standardized measures of weight, height and weight for height (CDC Anthropometric Software Package (CASP) for use on the Personal Computer, Version 3.0, 1987). That program flags all data that cannot be computed (data out of range, age or sex information not available, etc). All flagged data were discarded without further investigation. In addition, data presenting as Z scores of less than -6 or greater than +6 were treated as outliers and were discarded from all analyses. From these same outputs, but without exclusions based on very high or very low Z scores, distributions of weights and heights by centiles of the reference population (e.g. proportion of individuals falling below the reference 5th centile, etc) were prepared using PROC FREQ of SAS PC (Version 6.02, SAS Institute Inc, Cary, North Carolina).

To prepare files for plotting (see body of report) data were pooled by age intervals. Birth data were restricted to information recorded within 72 hours of birth. For two projects only weights were available in the birth files. From 0.5 to 12.5 months, data were grouped for one month periods (age taken as midpoint of the interval). From 12.5 to 30.5 months, pooling was by two month intervals. After 30.5 months, the interval used was 4 months, again assigning the midpoint of the interval as age for plotting. These groupings served to increase the numbers of data available for any one plotting point. To be included in the graphs, it was required that there be at least 15 data represented. No attempt was made to take account of repeated measures on the same individual (i.e. target individuals with longitudinal data sets). Best fit lines were prepared by running linear regression models of weight or height Z scores on age, again ignoring the presence of repeated measures, and using only data collected after 12 months and before 12 years of age. Lines were fitted to individual data and actual ages. The results are shown below (outlying data were not excluded from these analyses):

EGYPT	Weight Z score = - 0.913 + 0.002780 Age	N = 1780	RMSE = 1.079
	Height Z score = - 1.944 + 0.007994 Age	N = 1780	RMSE = 1.140
	Wt for Ht Z score = 0.148 + 0.001611 Age	N = 1780	RMSE = 1.057
KENYA	Weight Z score = - 1.628 + 0.003252 Age	N = 4058	RMSE = 0.870
	Height Z score = - 2.164 + 0.006203 Age	N = 4058	RMSE = 1.007
	Wt for Ht Z score = - .526 + 0.001645 Age	N = 4058	RMSE = 0.840
MEXICO	Weight Z score = - 1.460 + 0.003083 Age	N = 1931	RMSE = 0.876
	Height Z score = - 2.220 + 0.006956 Age	N = 1931	RMSE = 1.019
	Wt for Ht Z score = - .281 + 0.001987 Age	N = 1931	RMSE = 0.826

(For weight and height Z scores, the slopes were significantly different from 0 in every case. Note that replicated measures on same subjects not taken into account.)

To prepare individual regression data, it was demanded that a subject provide at least 6 measures across a period of at least 8 months within defined windows of age. For toddlers, data from age 16.0 to age 32.9 months were included. For schoolers, the permitted age interval was 78 to 123.9 months. In all projects, group mean ages of data collection were close to 24 and 96 months for the two intervals. Regressions were run with PROC REG, SAS PC using models of the type HTZ = AGE; the models were run independently for each child meeting the selection criteria. Subjects were excluded from subsequent analyses if the Root Mean Square Error of the individual's regression exceeded 1.0 for toddler data or 1.2 for schooler data. It was assumed that these cases either included unreliable measurements or departed from the general assumption of a linear relationship between the z score and age. A particular subject might have been excluded from weight analyses or height analyses while included for the other.

In developing adult measures for inclusion in prediction models, it was demanded that there be at least 3 measures of weight for the individual. A single measurement of height was accepted. Most subjects provided many more measurements. Unfortunately, the data base used in developing these variables for the Egyptian population did not include anthropometric measures collected during pregnancy (these are in a separate data base in the Egypt files). This would have introduced some bias in relation to the other projects since weight gain is expected during pregnancy and since pregnant weight might be expected to show a relationship with child growth. For adult women, there were at least 8 measures of food intake required before an intake variable was admitted. This higher requirement was imposed to dampen the effect of wide intraindividual variation in intake measures (see Management Report) and to foster development of an index of usual household dietary pattern covering longer rather than shorter periods of time. In the case of the Mexico project, only intake data collected after Jan 1, 1985, were included. It is important to recognize that the intake and anthropometric data for adults did not hold a fixed temporal relationship to the data for the child. The adult data were treated as if they were "state variables" reflecting a general condition of parental sizes and of household dietary intake ratios (diet quality measures).

For purpose of comparison with data on children, Z scores were developed for adults using reference data for young adults, 25 to 34.9 years of age. Reported US data for this group were:

Sex	Mean Wt	SD Wt	Mean Ht	SD Ht
Males	79.883	15.875	176.78	7.37
Females	63.504	14.515	162.81	6.10

The Z score was calculated as: (Observed Wt - Ref Mean Wt) / Ref SD Wt. Height measures were substituted when appropriate. While use of these reference data have the advantage of continuity with the population from which the CDC norms were selected, it must be recognized that the adult data were not developed for analysis purposes (smoothing) as were the reference data for children. Care must be taken in drawing comparisons.

Tables 1-3 present summary statistics describing the variables used in the analyses. An Annex provides the actual data used in plotting figures presented in the report.

These data were used in prediction equations run with PROC REG of the SAS PC program, Version 6.02 (SAS Institute Inc, Cary, North Carolina). Tables 4 and 5 present the R square values from some of these regressions, indicating also the level of statistical significance achieved. Individual coefficients, other than the intercept, were inconsistently significant and difficult to interpret because of cross correlations. However the correlations between the dependent and independent variables (Tables 6). These provide insight into consistent and inconsistent relationships. The important features to note from the tables are the repeatedly seen relationships between parental size variables and both the actual Z scores (Table 4) and the parameters of individual regressions (Table 5) in the Kenya and Mexico data sets. Maternal size measures are the more consitent predictors as might be expected. There were suggestions of similar relationships in the Egypt data set but, for many analyses, the number of cases was small and the models lacked power (or were overparameterized). It is noteworthy as well that dietary quality variables explained a part of the variance even after taking into account the explanatory effect of parental size. This was particularly true in the Mexico project. It must be emphasized again that the diet quality variables related to all measures available for the woman. In the Mexico project, many of these dietary data would have been derived from time periods <u>after</u> the collection of anthropometric data on the child. These relationships may not be causative in the narrow biological sense of intake affecting an outcome. The diet quality measures <u>may</u> reflect other conditions of the microenvironment surrounding the child during early growth and development. The models did not test all possible dietary variables. The two chosen were available in common across all projects and, as suggested by the correlation matrices presented in Table 7, are probably representative of the major variations in "diet quality" measures.

Although not presented in the tables, the inclusion of sex of the child in regression models had very little effect on the extent of variance explained. The Z score effectively adjusts for expected differences in size between girls and boys as well as expected changes in absolute weight and height with age. Thus, in normal situations, differences between Z scores for boys and girls are <u>not</u> expected. The absence of differences in the present data set may then be taken as implying that there were no major gendre-related differentials in

the environmental / child care variables that may impact upon the growth of the children.

Other regression models (not shown) were tested. These included maternal size variables alone, maternal size coupled with sex of the infant with or without dietary variables, and models including all variables. No preferred model fitting all projects was detected and the models presented in Tables 4 and 5 were selected essentially on the basis that they included the independent variables of particular concern to the hypotheses at hand - that either genetic or stable environmental factors represented by parental size affected the growth and development of the child and that factors associated with the diet or other characteristics of the household also influenced development. Much further analysis, involving use of other of the many measures included in the CRSP data sets will be required to go beyond this level of interpretation. That is, for example, before it can be concluded that diet per se is an important influence on the pattern of physical growth and development, it should be examined in models that include measures of other aspects of the microenvironment - do such inclusions explain additional variance or do they interchange with the dietary measures in explaining the same components of the variance?

The models at hand permit a comparison of growth across the three projects. This can be seen in two dimensions. First, do growth rates differ between projects? Second, do achieved sizes (weight or height) at defined ages differ between projects? The mean slope of Z scores within toddlers and within schoolers approximated 0 (on average, children were growing along their expected "channel", given a small size at the start of the period).

When the slopes of change in weight or height Z scores across time were examined the results shown below were obtained:

Project	Age Group	Measure	N	Mean	Std	Prob>|T|
Egypt	Toddlers	Slope Wt Z	95	0.0402	0.0716	0.0001
		Slope Ht Z	95	0.0283	0.0510	0.0001
Kenya	Toddlers	Slope Wt Z	107	0.0094	0.0403	0.0181
		Slope Ht Z	107	0.0130	0.0420	0.0001
Mexico	Toddlers	Slope Wt Z	96	0.0131	0.0477	0.0084
		Slope Ht Z	96	0.0519	0.0502	0.0001
Egypt	Schoolers	Slope Wt Z	37	-0.0086	0.0318	0.1079
		Slope Ht Z	37	0.0053	0.0170	0.0672
Kenya	Schoolers	Slope Wt Z	134	-0.0137	0.0257	0.0001
		Slope Ht Z	134	-0.0110	0.0194	0.0001
Mexico	Schoolers	Slope Wt Z	108	-0.0061	0.0171	0.0004
		Slope Ht Z	108	0.0045	0.0210	0.0289

Essentially all of the slopes were significantly different from 0. Most of the slopes approximated 0! A slope of 0.05, the largest seen would represent a change of about 0.6 standard deviations across the year; this would be considered biologically important. Conversely a slope of 0.01 would represent only about 0.1 standard deviations in a year. The mean slopes of the best fit

lines for weight and height Z scores (see above), based on all individual measures between 12 months and 12 years without taking into account the presence of repeated measures on the same individuals, were all under 0.01. The mean estimated Z scores for weight and height were generally similar at ages 24 and 96 months (Tables 1-3).

A direct comparison between projects was undertaken by including data from the individual regression equations from all projects in a single model which included country as a class variable. Using this model (parameter = country) PROC GLM (SAS PC Version 6.02) performed an analysis of variance and permitted testing of the effect of country using the Bonferroni test to compare means. It was found that for both toddlers and schoolers, and for estimated weight Z scores at 24 and 96 and height scores at 96 months, children in the Egypt project differed from those in Kenya and Mexico (Significant at 5% level by Bonferroni test) whereas differences between Kenya and Mexico could not be established (application of Duncan's multiple t test suggested that these also were different). Comparisons of the slopes of weight and height Z score change showed a similar pattern in toddlers. Among schoolers, children in Kenya and Mexico differed from each other but not from those in Egypt with regard to change in weight Z scores. With regard to height change, both Egypt and Kenya differed from Mexico but not from each other.

These observations, together with the fall in Z scores during the first 12 months (Tables 1-3 and plots presented in body of report) strongly support a conclusion that for the populations of children examined in the three projects, the major "growth failure" took place before the end of the first year of life and that thereafter growth was relatively "normal" without much sign of catch up. It would appear that the "failure" occurs at similar times in the three projects (between about 4 months and 12 months). After 12 months the "stable pattern" suggests that there has been a differential in early growth among the projects. The greatest effect has been in the Kenyan population and the least in the Egyptian children with Mexicans falling between the others but close to Kenyan children.

Even though the foregoing describes the pattern of growth across childhood, it must be recognized that the slopes of change in Z scores within the toddler and schooler windows do show variation between individuals (Tables 1-3). In these relatively short time periods, all children do <u>not</u> grow at the same rate. In the next section of this report, the differences in growth rates within the toddler age window are explored in greater depth. This variance is in contrast to the evidence that across longer periods, the populations have stable patterns. The distinct conclusion must be that <u>within the status quo situation of these study populations the gains or losses in growth rates seen within shorter windows of time are offset by earlier or later changes in the opposite direction</u>. If this were not the case, one would expect to see a progressive increase in the variance of Z scores across ages (individuals becoming more diverse in response to continued differences in their microenvironments and associated growth rates). That does not appear to be the case (Tables 1-3). The notion of a continuation of a situation of growth that developed during early life is further strengthened by examination of adult Z scores (Tables 1-3). The height scores were consitent with those seen in children. The exception to the notion of stable Z scores is seen in the data

plots for Egypt, to some degree in the slopes of the regression lines for that project and in the comparison of adult Z scores with those for children. Although there is limited indication of catch up in linear growth, it is readily apparent that during childhood the Egyptian study group began to show increases in weight. The adults exhibit weights that approximate the US population particularly in females. Since heights do not match US heights, it can be inferred that adiposity is the explanation of the changes in Z scores. By inference the energy supply is sufficiently high, or the activity levels are sufficiently low, that tissue deposition of energy reserves is possible in that community - more possible than in either Kenya or Mexico although Mexican females also showed an increase in Z scores for weight between children and adults.

Examination of Relationship Between Intake, Growth and Achieved Size Within Toddlers

In an interproject comparative exploration of predictors of toddler growth rates, longitudinal samples were drawn in accordance with procedures described in the project reports. In these studies weights and heights were not converted to Z scores. However the data for each child were converted to linear regression equations so that body size and growth could be described in terms of an intercept at a specified age (e.g. 18, 24 or 30 months) and a slope. It was demonstrated that, for this age group a linear regression gave the best fit of data. It should be recognized that in these analyses, a positive slope is expected for a child who is growing. In the analyses presented above, the expectation for normal growth is a 0 slope (no change in age and sex adjusted Z scores when child shows expected normal increase in absolute weight or height).

The initial thrust of these analyses was a search for the best regression model for application across projects. The independent variables incorporated in the various models tested included age, sex, a variable representing the proportion of study months during which the child received breast milk, and the following measures of the child's dietary intake averaged over the whole year between 18 and 30 months of age: energy, total protein, animal protein, carbohydrate, fat, and the ratios fat as % energy, total protein as % energy, animal protein as % energy, and animal protein as % total protein. (Without inclusion of the ratios, the model has been designated the DIET5 model; with inclusion of ratios it is designated DIET8.) The models were also run with and without inclusion of a measure of achieved weight or height. The dependent variables were the intercept at 30 or 96 months and the slopes of weight or height change. Models were run using all Mexico project intake data and using only data collected with methodology in place after January 1, 1985 (a much smaller n). They were run with the primary Egyptian intake data and with data adjusted to take into account the apparent bias introduced by one interviewer. In keeping with presentations in the original project and management reports, only the new method data from Mexico and adjusted intake data from Egypt are presented in this report. The models were run also with omission of suspect "outlying" cases to test their influence on the outcomes. Two subjects in the Mexico data set were found to have undue influence on many of the relationships detected; this, and the small sample size, argues for

considerable caution in interpreting the analyses of the Mexico data sets. The analyses presented in this report include the "suspect" cases.

The net outcome of these many analyses was an essential inability to develop a single preferred model. Variables that appeared to contribute in one project were not demonstrably contributory in another. Yet omission of those variables from either or both would distort the comparison of models. Comparison of the coefficients of individual variables across projects was uninterpretable since the cross correlations differed and indeed the sign of the coefficient within a particular model might differ across projects as well as between models within a project. This is not unexpected and cannot be taken to imply that the effect really differed. Rather, it suggests that the effects could not be isolated.

In an attempt to overcome some of these difficulties, and to make interpretation more meaningful, the basic models (sex, breast feeding measure, age and either 5 or 8 dietary variables) were run in a manner that permitted estimation of the effect of adding/removing 100 kcal of food. To take into account one of the underlying questions arising from CRSP project analyses and from the growth pattern analyses presented above, these models also permitted estimation of the impact of changing the composition of the 100 kcal added or removed. The analyses are not to be overinterpreted. By design the "additions" or "removals" represent differences falling within the range of original observations (estimated intakes). There can be but limited assurance that real additions or deletions would have the same effect. Nevertheless this approach was seen as one offering a realistic perspective of possible dietary influences. The "foods" so modelled simulated the addition of:

100 kcal of average diet (composition = mean intake pattern of toddlers in the particular project)
100 kcal 3.3% fat milk (composition = 5.47 g fat + 5.33 g animal protein + 7.33 g carbonydrate)
100 kcal rice (composition = 0.06 g fat + 2.0 g plant protein + 23.0 g carbohydrate)

The results of these simulations are shown in Table 8. Only in the Kenya project was it possible to demonstrate statistically significant effects of the addition of 100 kcal and even here the effect was demonstrable only when the simulated addition was of the same composition as the usual diet. The effects were not large, amounting to an additional gain of about 0.56 cm in height and 0.25 kg in weight over the year. However, small gains of this magnitude are consistent with effects seen in child feeding programs (when children have not been selected as having major anthropometric deficits). The result is realistic.

In the Mexico project, there initially appeared to be an effect associated with the addition of 100 kcal of milk, in keeping with correlation analyses that had suggested strong associations between animal source protein or energy and physical growth as well as other outcomes. However, as noted above, when two outlying subjects were omitted from the analyses, the effect was abolished. It would appear that these two subjects may have been exerting undue influence and hence were distorting the analyses.

If one simply examines the magnitudes of the estimated effects, setting aside the confidence intervals and statistical significance, there is an impression that the Egypt project children would show smaller responses to added intakes than would either Mexican or Kenyan children. This is in keeping with the general impression arising from the anthropometric measures and other data that environmental conditions, including dietary intakes, were more constraining in Kenya than in the other projects (certainly reported intakes were much lower) and that the level of dietary energy intake may be least constraining in Egypt.

Perhaps the most important aspect of these multivariate analyses is an expression of the need for caution in interpreting simple regression analyses. Although the Kenya project has reported repeated associations between fat intake and a number of outcomes (see Project Report), and the Mexico Project has reported even stronger associations between animal source energy and protein intake and many outcomes (see Project Report), the present analyses fail to offer clear support for the conclusion that this is a true diet effect. That is, the two simulated additions would mimic differential change in fat intake or animal protein intake with the usual diet as a control. Although the direction of changes in the estimated effects was consistent with the hypotheses, the confidence intervals widened and statistical significance was lost. Admittedly these models are "overparamterized" and intercorrelations abound. However those cross correlations exist also when single variables are selected for examination - one cannot be sure what is really being tested. Unless and until a clearer approach to sorting this out can be developed, one must be extremely cautious in suggesting from any of the analyses reported to date that increased food intakes (food supplementation programs) in toddlers would have beneficial effect on growth. The data from Kenya are suggestive that this might be the case but they are far from certain. Explicitly there is not sufficient justification for advocating increased animal protein or fat intakes based on correlation analyses.

Table 1. Summary Statistics of Data Set Available for Analyses
Egypt Project

Variable	N	Mean	Std Dev
Adult Variables *			
Adult Male Mean Weight	228	69.392	11.669
Adult Male Mean Height	145	166.462	13.737
Adult Female Mean Weight	246	63.777	11.498
Adult Female Mean Height	218	155.350	5.897
Adult Male Weight Z Score **	228	-0.661	0.735
Adult Male Height Z Score **	145	-1.400	1.864
Adult Female Weight Z Score **	246	0.019	0.792
Adult Female Height Z Score **	218	-1.223	0.967
Maternal Total Prot % Energy	277	12.783	0.868
Maternal An Prot % Energy	277	4.021	1.131
Maternal Total Fat % Energy	277	22.355	3.268
Maternal Anim Fat % Energy	277	10.790	3.681
Maternal An Prot % Tot Prot	277	28.729	6.916
Maternal An Fat % Tot Fat	277	43.752	12.080
Actual Z Scores			
Wt Z at Birth	96	-0.105	1.040
Wt Z at 6 mo	66	-1.120	1.265
Wt Z at 30 mo	61	-0.701	1.151
Wt Z at 96 mo	62	-0.610	0.861
Ht Z at Birth	0	.	.
Ht Z at 6 mo	31	-0.864	1.245
Ht Z at 30 mo	56	-1.863	0.974
Ht Z at 96 mo	63	-0.958	0.961
Parameters From Individual Regressions - Toddlers			
Estimated WTZ at 24 mo	95	-0.950	0.959
Estimated WTZ at 30 mo	95	-0.709	0.983
Slope WTZ with Age	95	0.040	0.072
Root Mean Sq Error, WTZ	95	0.424	0.205
Estimated HTZ at 24 mo	95	-1.834	1.023
Estimated HTZ at 30 mo	95	-1.664	1.061
Slope HTZ with Age	95	0.028	0.051
Root Mean Sq Error, HTZ	95	0.421	0.167
Parameters From Individual Regressions - Schoolers			
Estimated WTZ at 96 mo	37	-0.594	0.751
Slope WTZ with Age	37	-0.009	0.032
Root Mean Sq Error, WTZ	37	0.220	0.127
Estimated HTZ at 96 mo	37	-1.077	0.860
Slope HTZ with Age	37	0.005	0.017
Root Mean Sq Error, HTZ	37	0.148	0.129

* Based on all individuals used in any of the regression analyses
** See text for explanation of derivation

Table 2. Summary Statistics of Data Set Available for Analyses
Kenya Project

Variable Label	N	Mean	Std Dev
Adult Variables *			
Adult Male Mean Weight	466	55.100	6.906
Adult Male Mean Height	455	165.429	6.544
Adult Female Mean Weight	470	51.966	7.328
Adult Female Mean Height	470	154.548	5.522
Adult Male Weight Z Score **	466	-1.561	0.435
Adult Male Height Z Score **	455	-1.540	0.888
Adult Female Weight Z Score **	470	-0.795	0.505
Adult Female Height Z Score **	470	-1.354	0.905
Maternal Total Prot % Energy	464	11.604	0.782
Maternal An Prot % Energy	464	1.016	0.689
Maternal Total Fat % Energy	464	13.734	2.451
Maternal Anim Fat % Energy	0	.	.
Maternal An Prot % Tot Prot	464	8.617	5.688
Maternal An Fat % Tot Fat	0	.	.
Actual Z Scores			
WT Zscore, Birth	117	-0.220	1.378
WT Zscore, 6 M	103	-0.674	1.080
WT Zscore, 30 M	88	-1.380	0.845
WT Zscore, 8 Y	150	-1.322	0.757
Ht Zscore, Birth	0	.	.
Ht Zscore, 6 M	103	-1.787	0.991
Ht Zscore, 30 M	88	-1.727	0.967
Ht Zscore, 8 Y	150	-1.600	0.940
Parameters From Individual Regressions - Toddlers			
Est WTZ at 24 m	107	-1.564	0.863
Est WTZ at 30 m	107	-1.508	0.906
Slope WTZ with Age	107	0.009	0.040
Root Mean Sq Error, WTZ	107	0.282	0.104
Est HTZ at 24 m	107	-2.064	0.921
Est HTZ at 30 m	107	-1.949	0.968
Slope HTZ with Age	107	0.019	0.042
Root Mean Sq Error, HTZ	107	0.360	0.153
Parameters From Individual Regressions - Schoolers			
Est WTZ at 8 yr	134	-1.364	0.751
Slope WTZ with Age	134	-0.014	0.026
Root Mean Sq Error, WTZ	134	0.184	0.092
Est HTZ at 8 yr	134	-1.615	0.974
Slope HTZ with Age	134	-0.011	0.019
Root Mean Sq Error, HTZ	134	0.114	0.063

* Based on all individuals used in any of the regression analyses
** See text for explanation of derivation

Table 3. Summary Statistics of Data Set Available for Analyses
Mexico Project

Variable	N	Mean	Std Dev
Adult Parameters *			
Adult Male Mean Weight	308	65.727	9.712
Adult Male Mean Height	308	165.967	5.799
Adult Female Mean Weight	364	58.995	8.883
Adult Female Mean Height	362	152.982	5.693
Adult Male Weight Z Score **	308	-0.892	0.612
Adult Male Height Z Score **	308	-1.467	0.787
Adult Female Weight Z Score **	364	-0.311	0.612
Adult Female Height Z Score **	362	-1.611	0.933
Maternal Total Prot % Energy	353	11.374	0.924
Maternal An Prot % Energy	353	2.058	1.400
Maternal Total Fat % Energy	353	13.976	4.154
Maternal Anim Fat % Energy	0	.	.
Maternal An Prot % Tot Prot	353	16.536	9.832
Maternal An Fat % Tot Fat	0	.	.
Observed Z Scores			
WT Zscore, Birth	61	-0.411	0.906
WT Zscore, 6 M	68	-0.617	1.135
WT Zscore, 30 M	89	-1.266	0.888
WT Zscore, 8 Y	129	-1.157	0.732
Ht Zscore, Birth	52	-0.311	0.951
Ht Zscore, 6 M	68	-1.250	0.825
Ht Zscore, 30 M	50	-1.862	1.043
Ht Zscore, 8 Y	126	-1.556	0.917
Individual Regression Parameters - Toddlers			
Est WTZ at 24 m	96	-1.312	0.851
Est WTZ at 30 m	96	-1.233	0.849
Slope WTZ with Age	96	0.013	0.048
Root Mean Sq Error, WTZ	96	0.390	0.169
Est HTZ at 24 m	96	-2.098	1.029
Est HTZ at 30 m	96	-1.787	1.007
Slope HTZ	96	0.052	0.050
Root Mean Sq Error, HTZ	95	0.291	0.135
Individual Regression Parameters - Schoolers			
Est WTZ at 96 m	108	-1.152	0.676
Slope WTZ with Age	108	-0.006	0.017
Root Mean Sq Error, WTZ	108	0.195	0.127
Est HTZ at 96 m	108	-1.522	0.842
Slope HTZ with Age	108	0.004	0.021
Root Mean Sq Error, HTZ	108	0.142	0.204

* Based on all individuals used in any of the regression analyses
** See text for explanation of derivation

Table 4. R Square Values From Linear Regressions Predicting the Z Scores of Achieved Size at Fixed Ages

Dependent and Independent Variables	Project		
	EGYPT	KENYA	MEXICO
WTZ at birth			
Mat & Pat Wt Ht	0.122	0.107 *	0.065
Mat & Pat Wt Ht + Diet	0.163	0.106	0.106
Diet alone	0.012	0.058	0.058
WTZ at 6 m			
Mat & Pat Wt Ht	0.060	0.140 **	0.287 **
Mat & Pat Wt Ht + Diet	0.259	0.192 **	0.327 **
Diet Alone	0.167 **	0.071	0.056
WTZ at 30 m			
Mat & Pat Wt Ht	0.188	0.195 **	0.212 **
Mat & Pat Wt Ht + Diet	0.269 *	0.204 **	0.236 **
Diet Alone	0.036	0.014	0.127 **
WTZ at 96 m			
Mat & Pat Wt Ht	0.373 *	0.263 **	0.189 **
Mat & Pat Wt Ht + Diet	0.529 *	0.269 **	0.250 **
Diet Alone	0.044	0.018	0.138 **
HTZ at Birth			
Mat & Pat Wt Ht	not	not	0.163
Mat & Pat Wt Ht + Diet	Available	Available	0.228
Diet Alone			0.040
HTZ at 6 m			
Mat & Pat Wt Ht	0.662	0.170 *	0.279 **
Mat & Pat Wt Ht + Diet	0.797	0.221 **	0.199 **
Diet Alone	0.087	0.030	0.025
HTZ at 30 m			
Mat & Pat Wt Ht	0.184	0.200 **	0.506 **
Mat & Pat Wt Ht + Diet	0.197	0.269 **	0.600 **
Diet Alone	0.011	0.053	0.336 **
HTZ at 96 m			
Mat & Pat Wt Ht	0.328 *	0.205 **	0.166 **
Mat & Pat Wt Ht + Diet	0.579 *	0.218 **	0.172 **
Diet Alone	0.058	0.028	0.043

Dietary variables included were: animal protein as % energy and total fat as % energy. These were selected as being less interdependent than other combinations.

* $P < .05$ ** $P < .005$

Table 5A. R Square Values from Regression Models Predicting the Parameters of Regression Lines Derived for Individual Children

TODDLERS

Regression Variables		Project					
		Egypt		Kenya		Mexico	
Dependent	Independent	N	Rsquare	N	Rsquare	N	Square
Slope WTZ	Anthro Only	57	0.023	104	0.081	77	0.025
	Diet Only	85	0.021	107	0.008	96	0.010
	Anthro + Diet	52	0.025	104	0.097	77	0.046
RMSE WTZ	Anthro Only	57	0.070	104	0.022	77	0.048
	Diet Only	85	0.011	107	0.127 ***	96	0.024
	Anthro + Diet	52	0.099	104	0.139 *	77	0.089
EST WTZ 24	Anthro Only	57	0.264 ***	104	0.146 ***	77	0.151 *
	Diet Only	85	0.016	107	0.033	96	0.110 ***
	Anthro + Diet	52	0.212 **	104	0.174 ***	77	0.170 *
EST WTZ 30	Anthro Only	57	0.256 **	104	0.168 ***	77	0.153 *
	Diet Only	85	0.005	107	0.039	96	0.124 *
	Anthro + Diet	52	0.323 **	104	0.204 ***	77	0.176 *
Slope HTZ	Anthro Only	57	0.029	104	0.032	77	0.091
	Diet Only	85	0.043	107	0.101 ***	96	0.012
	Anthro + Diet	52	0.075	104	0.138 **	77	0.115
RMSE HTZ	Anthro Only	57	0.178 *	104	0.043	76	0.081
	Diet Only	85	0.063	107	0.059 *	96	0.002
	Anthro + Diet	52	0.245 *	104	0.093	76	0.101
EST HTZ 24	Anthro Only	57	0.396 ***	104	0.163 ***	77	0.144 *
	Diet Only	85	0.078	107	0.077 **	96	0.101 ***
	Anthro + Diet	52	0.445 ***	104	0.247 ***	77	0.163 *
EST HTZ 30	Anthro Only	57	0.371 ***	104	0.164 ***	77	0.184 ***
	Diet Only	85	0.050	107	0.112 ***	96	0.107 ***
	Anthro + Diet	52	0.417 ***	104	0.284 ***	77	0.194 **

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$

"Anthro" = Maternal Weight and Height + Paternal Weight and Height

"Diet" = Maternal Fat as % Energy + Maternal Animal Protein as % Energy

Table 5B. R Square Values from Regression Models Predicting the Parameters of Regression Lines Derived for Individual Children

SCHOOLERS

Regression Variables		Project					
		Egypt		Kenya		Mexico	
Dependent	Independent	N	Rsquare	N	Rsquare	N	Square
SLOPE WTZ	Anthro Only	18	0.309	127	0.058	98	0.018
	Diet Only	33	0.162	134	0.002	107	0.015
	Anthro + Diet	17	0.658 *	127	0.069	98	0.049
RMSE WTZ	Anthro Only	18	0.090	127	0.027	98	0.079
	Diet Only	33	0.238 *	134	0.000	107	0.003
	Anthro + Diet	17	0.211	127	0.029	98	0.085
EST WTZ 96	Anthro Only	18	0.405	127	0.314 ***	98	0.191 ***
	Diet Only	33	0.021	134	0.031	107	0.151 ***
	Anthro + Diet	17	0.527	127	0.316 ***	98	0.260 ***
SLOPE HTZ	Anthro Only	18	0.211	127	0.137 ***	98	0.067
	Diet Only	33	0.068	134	0.034	107	0.008
	Anthro + Diet	17	0.269	127	0.166 ***	98	0.074
RMSE HTZ	Anthro Only	18	0.362	127	0.025	98	0.006
	Diet Only	33	0.037	134	0.026	107	0.012
	Anthro + Diet	17	0.366	127	0.063	98	0.020
EST HTZ 96	Anthro Only	18	0.211	127	0.238 ***	98	0.166 ***
	Diet Only	33	0.011	134	0.044	107	0.070
	Anthro + Diet	17	0.392	127	0.248 ***	98	0.189

* P < 0.05 ** P < 0.01 *** P < 0.001

"Anthro" = Maternal Weight and Height + Paternal Weight and Height

"Diet" = Maternal Fat as % Energy + Maternal Animal Protein as % Energy

Table 6A. Correlations Between Independent and Dependent Regression Variables (See Tables 4 and 5)

A. Weight Z Scores

Predictor Variables	Measure of Achieved Child Size: Actual Z Score, Birth	Actual Z Score, 6 m	Actual Z Score, 30 m	Actual Z Score, 96 m	Estimated Z Score, 24 m	Estimated Z Score, 30 m	Estimated Z Score, 96 m
EGYPT PROJECT							
Maternal Wt	0.369**	0.037	0.067	0.293*	0.269**	0.273**	0.348*
Maternal Ht	0.006	0.017	0.273*	0.344*	0.294**	0.329**	0.196
Paternal Wt	0.114	0.031	0.243	0.494**	0.208	0.222	0.480**
Paternal Ht	0.025	0.161	0.226	0.292	0.139	0.199	0.589**
Fat % Energy	0.105	-.195	-.015	0.092	0.084	0.024	-.067
An Prot % En	0.086	0.187	0.151	-.111	0.124	0.066	-.145
KENYA PROJECT							
Maternal Wt	0.294**	0.309**	0.338**	0.422**	0.243*	0.293**	0.458**
Maternal Ht	0.078	0.087	0.234*	0.332**	0.140	0.185	0.376**
Paternal Wt	0.046	0.084	0.238*	0.327**	0.295**	0.276**	0.363**
Paternal Ht	0.066	0.129	-.020	0.192*	0.115	0.077	0.257**
Fat % Energy	0.147	0.216	-.004	0.132	0.103	0.103	0.176
An Prot % En	0.055	0.267**	-.081	0.120	-.020	-.020	0.157
MEXICO PROJECT							
Maternal Wt	0.238	0.475**	0.390**	0.355**	0.369**	0.331**	0.394**
Maternal Ht	0.178	0.323**	0.336**	0.233**	0.350**	0.325**	0.253**
Paternal Wt	-.071	0.126	0.330**	0.293*	0.220	0.252*	0.229*
Paternal Ht	0.009	0.059	0.221	0.062	0.134	0.162	0.036
Fat % Energy	0.238	0.059	0.252*	0.355**	0.267**	0.264**	0.374**
An Prot % En	0.170	0.190	0.353**	0.342**	0.332**	0.350**	0.356**

* Statistically significant $P < 0.05$
** Statistically significant $P < 0.01$

Table 6B. Correlations Between Independent and Dependent Regression Variables (See Tables 4 and 5)

B. Height Z Scores

Predictor Variables	Measure of Achieved Child Size: Actual Z Score, Birth	Actual Z Score, 6 m	Actual Z Score, 30 m	Actual Z Score, 96 m	Estimated Z Score, 24 m	Estimated Z Score, 30 m	Estimated Z Score, 96 m
EGYPT PROJECT							
Maternal Wt		0.300	-.006	0.240	0.303**	0.304**	0.347*
Maternal Ht		0.374	0.205	0.497**	0.329**	0.406**	0.235
Paternal Wt		0.386	0.270	0.220	0.207	0.250*	0.301
Paternal Ht		0.623*	0.213	0.257	0.008	0.042	0.296
Fat % Energy		-.123	0.098	0.153	0.160	0.146	0.066
An Prot % En		0.173	0.087	-.075	0.278**	0.220*	0.100
KENYA PROJECT							
Maternal Wt		0.228*	0.328**	0.304**	0.232*	0.232*	0.307**
Maternal Ht		0.153	0.310**	0.403**	0.224*	0.217*	0.429**
Paternal Wt		0.224*	0.244*	0.239**	0.305**	0.314**	0.263**
Paternal Ht		0.337**	0.045	0.195*	0.217*	0.194*	0.255**
Fat % Energy		-.017	0.160	0.154	0.237*	0.260**	0.209*
An Prot % En		-.109	0.011	0.164*	0.087	0.060	0.188*
MEXICO PROJECT							
Maternal Wt	0.249	0.383**	0.437**	0.300**	0.281**	0.321**	0.313**
Maternal Ht	0.219	0.468**	0.504**	0.237**	0.323**	0.335**	0.282**
Paternal Wt	-.007	0.114	0.598**	0.236**	0.248*	0.289*	0.202*
Paternal Ht	0.036	0.018	0.403**	0.201*	0.160	0.246*	0.196*
Fat % Energy	0.200	0.150	0.263	0.207*	0.219*	0.200*	0.258**
An Prot % En	0.150	0.150	0.483**	0.148	0.313**	0.314**	0.240*

* Statistically significant $P < 0.05$
** Statistically significant $P < 0.01$

Table 7. Correlations Among Maternal Dietary Variables*

Variables	Variables					
	Protein % Energy	An Prot % Energy	An Prot % Prot	Fat % Energy	An Fat % Energy	An Fat % Fat
			A. Egypt Project			
Prot % Energy	1	0.716	0.551	0.120	0.690	0.256
An Prot % Energy		1	0.958	0.541	0.690	0.618
An Prot % Prot			1	0.600	0.788	0.730
Fat % Energy				1	0.755	0.519
An Fat % Energy					1	0.929
An Fat % Fat						1
			B. Kenya Project			
Prot % Energy	1	0.060	-0.079	0.046		
An Prot % Energy		1	0.962	0.829		
An Prot % Prot			1	0.826		
Fat % Energy				1		
			C. Mexico Project			
Prot % Energy	1	0.728	0.653	0.498		
An Prot % Energy		1	0.988	0.787		
An Prot % Prot			1	0.800		
Fat % Energy				1		

* For numbers of observations included, see Tables 1-3

Table 8. Potential Impact of Changes in Intake of Toddlers by 100 kcal: Simulations Based Upon Regression Models

Country	Regression Model	Simulated Addition: Same Diet EST	SE	T	P	Milk EST	SE	T	P	Rice EST	SE	T	P
EGYPT													
Height at 30 m													
	Diet5	.32	.24	1.33	.19	.46	.48	0.96	.34	.13	.42	0.31	.75
	Diet8	.34	.25	1.38	.17	.53	.49	1.08	.28	.26	.45	0.58	.56
Height Slope													
	Diet5	.15	.16	0.92	.36	-.17	.32	-.53	.60	.09	.30	0.33	.74
	Diet8	.11	.16	0.65	.52	-.22	.33	-.65	.52	-.03	.30	-.09	.93
Weight at 30 m													
	Diet5	.04	.09	0.49	.63	.11	.18	0.63	.53	.06	.15	0.41	.68
	Diet8	.04	.09	0.47	.64	.14	.18	0.77	.44	.08	.16	0.47	.64
Weight Slope													
	Diet5	-.06	.07	-.83	.41	-.09	.14	-.65	.52	-.06	.12	-.47	.64
	Diet8	-.10	.07	-1.47	.15	-.14	.13	-1.03	.30	-.17	.12	-1.45	.15
KENYA													
Height at 30 m													
	Diet5	.56	.19	2.88	.01	1.62	1.05	1.55	.13	.26	.38	0.68	.50
	Diet8	.57	.19	2.95	.00	1.58	1.05	1.50	.14	.30	.38	0.79	.43
Height Slope													
	Diet5	.19	.12	1.67	.10	.03	.63	0.04	.97	.01	.23	0.03	.98
	Diet8	.18	.11	1.59	.12	-.06	.62	-.09	.93	.05	.22	0.22	.83
Weight at 30 m													
	Diet5	.23	.08	2.98	.00	.14	.41	0.34	.73	.29	.15	1.94	.06
	Diet8	.25	.08	3.29	.00	.15	.41	0.37	.71	.31	.15	2.06	.04
Weight Slope													
	Diet5	.07	.04	1.64	.10	-.06	.22	-.28	.78	.08	.08	0.99	.33
	Diet8	.07	.04	1.80	.07	-.02	.22	-.13	.90	.10	.08	1.21	.23
MEXICO													
Height at 30 m													
	Diet5	.24	.23	1.03	.31	1.95	.64	3.07	.00	-.18	.37	-.48	.63
	Diet8	.39	.24	1.65	.11	2.50	.88	2.84	.01	.08	.36	0.24	.81
Height Slope													
	Diet5	-.06	.12	-.46	.65	.74	.33	2.24	.03	.26	.19	1.37	.18
	Diet8	-.03	.14	-.22	.83	.79	.52	1.53	.14	.27	.20	1.33	.19
Weight at 30 m													
	Diet5	.09	.08	1.04	.31	.66	.24	2.72	.01	-.05	.14	-.43	.67
	Diet8	.06	.08	0.73	.47	.55	.29	1.90	.07	.04	.13	0.29	.78
Weight Slope													
	Diet5	.05	.05	0.95	.35	.31	.14	2.20	.04	.11	.08	1.41	.17
	Diet8	.03	.05	0.55	.59	.29	.19	1.54	.14	.14	.08	1.74	.09

Table 8, Cont'd.
Potential Impact of Changes in Intake of Toddlers by 100 kcal:
Simulations Based Upon Regression Models

Country	Regression Model	Simulated Addition: Same Diet EST	SE	T	P	Milk EST	SE	T	P	Rice EST	SE	T	P
MEXICO (OMITTING TWO DIVERGENT SUBJECTS) (21030975 and 41321309)													
Height at 30 m													
	Diet5	.16	.23	0.68	.50	1.01	.97	1.05	.30	-.04	.39	-.11	.92
	Diet8	.30	.20	1.49	.15	.44	.95	0.47	.64	.09	.42	0.21	.84
Height Slope													
	Diet5	-.09	.12	-.73	.47	.36	.51	0.70	.49	.34	.21	1.61	.12
	Diet8	-.08	.13	-.64	.53	.51	.62	0.87	.39	.28	.27	1.02	.32
Weight at 30 m													
	Diet5	.06	.09	0.75	.46	.54	.36	1.48	.15	-.05	.15	-.35	.73
	Diet8	.08	.07	1.09	.29	.28	.31	0.92	.37	.11	.14	0.82	.42
Weight Slope													
	Diet5	.05	.05	0.92	.37	.38	.21	1.80	.08	.10	.09	1.14	.26
	Diet8	.05	.05	0.89	.38	.29	.21	1.35	.19	.16	.10	1.65	.11

Explanatory Comments.

EST = Estimate of change with a 100 kcal addition. Units are cm, cm/y, kg and kg/y for Height at 30 m, Height Slope, Weight at 30 m and Weight Slope respectively.

SE = Standard Error of the estimate.

T = Value of T

P = Probability (Statistical Significance can be judged by choosing an appropriate probability value)

Diet5 = Regression model of named variable on age including sex, a measure of proportion of months that child was offered breast milk, actual height or weight at 18 months and the following dietary variables based on the child's average intake over the 18-30 months of age period:

Energy, Total Protein, Animal Protein, Total Fat, Carbohydrate

Diet8 = Above regression model with inclusion of the following "diet quality" variables:

Fat Energy/Total Energy, Protein Energy/Total Energy, and Animal Protein Energy/Total Energy

In analyses of Mexico Project data, subjects providing dietary data after Jan 1, 1985 were used. In this small sample, two subjects had unusual levels of intake together with deviant anthropometry; analyses were run with and without these subjects. In analyses of the Egypt Project data, dietary data had been adjusted to take into account the effect of the holy day (Fridays) and to take account of a bias associated with one interviewer (See Egypt Project Report)