Factors Associated with Growth in the First Year of Life in Egyptian Children: Implications for the Double Burden of Malnutrition

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Abbreviations List

CDA	community development association
CHW	community health worker
LAZ	length for age Z-score
WAZ	weight for age Z-score
WHZ	weight for height Z-score

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The Maternal and Child Health Integrated Program (MCHIP) is the U.S. Agency for International Development Bureau for Global Health's flagship maternal, neonatal and child health (MNCH) program. MCHIP supports programming in MNCH, immunization, family planning, malaria and HIV/AIDS, and strongly encourages opportunities for integration. Crosscutting technical areas include water, sanitation, hygiene, urban health and health systems strengthening.

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Executive Summary

INTRODUCTION

Linear growth in infancy and early childhood is critical to the attainment of human capital and economic development of a society. Stunted children often become adults of small stature, with limited work productivity and reduced lifetime wage earnings. A number of factors, including diarrheal illness, febrile infections, breastfeeding practices, and dietary quantity and quality of complementary foods, are known to be associated with growth. The presence of these factors and their relative importance in influencing growth vary by setting and the child's age.

Stunting remains an important problem in Egypt, with approximately one-third of children < 5 years of age affected. During the last several years, food prices and food insecurity have risen in Egypt as a consequence of successive crises, including the avian influenza epidemic (2006) and food, fuel, and financial crises (2007–2009). An increase in the prevalence of stunting from 2005 to 2008 was documented in Lower Egypt, which coincided with an avian influenza outbreak, but whether it was related to the outbreak or due to other factors remains unclear. A similar increase in stunting prevalence did not occur in Upper Egypt during the same period.

The primary objective of this study was to determine whether there were differences between Lower Egypt and Upper Egypt in growth patterns and factors related to growth in within the context of a U.S. government-funded maternal and child health integrated program. Our secondary objective was to examine the relationship between weight and length to ascertain if weight loss in any two-month interval contributes to stunting at 12 months of age.

METHODS

From 2009 to 2014, the Maternal and Child Health Integrated Program (MCHIP) was the United States Agency for International Development (USAID) flagship project on maternal, newborn, and child health. The program focused on addressing the underlying causes of maternal, newborn, and child mortality. MCHIP carried out the SMART project (Community-based Initiatives for a Healthy Life) in Egypt to improve health service delivery and nutritional status through private-sector community development association clinics and community health workers. The study sites reflect represent two of six SMART project governorates and allowed for comparisons of infant and young child feeding practices and other related factors between regions with the highest (Lower Egypt) and lowest (Upper Egypt) levels of stunting according to the 2008 Egypt Demographic and Health Survey[1]. The two study sites were Qaliobia governorate in Lower Egypt and Sohag governorate in Upper Egypt. The sample of mother-infant pairs was drawn from SMART project sites in three villages in Lower Egypt and five villages in Upper Egypt.

The SMART project identified and mapped all pregnant women in project communities. SMART project volunteers notified community health workers (CHWs) of births by study participants in designated study catchment areas. All pregnant women in Lower and Upper Egypt study areas were recruited at SMART project community development association (CDA) private clinics during a two-month period (February–March 2013). Eligibility criteria for women to participate in the study included: ≥ 18 years or age, last trimester of pregnancy, participation in the SMART project, and residence in Kafr Shokr district, Qaliobia, Lower Egypt, or El-Maragha district, Sohag, Upper Egypt. During routine project home visits, SMART project CHWs obtained oral consent from women and their husbands for the participation of the mother-infant pairs. Data were collected from April 2013 to June 2014.

Weight and recumbent length were measured at 0 (birth), 2, 4, 6, 8, 10, and 12 months of age using SECA digital infant scales (0.1 kg increment) and plastic length boards (in duplicate, to nearest 0.1 cm). Birth measurements were taken by SMART project CHWs during routine project home visits within the first 36 hours after the birth of the infant, regardless of where the delivery took place. Anthropometric Z-scores were calculated using the World Health Organization (WHO) growth standard. Underweight was defined as weight-for-age Z-score WAZ <- 2 SD; stunting was defined as length-for-age Z-score LAZ <-2 SD; wasting was defined as weight-for-length Z-score WLZ <-2 SD; and overweight was defined as weight-for-length Z-score WLZ > 2 SD. Mother's height was measured two months after birth to the nearest 0.1 cm using tape measures fixed to the wall. Maternal and socioeconomic characteristics were measured at two months postpartum during the first clinic visit using an administered questionnaire.

During each clinic visit following birth, study CHWs conducted interviews with study participants. Maternal report of child illness was collected at 2, 4, 6, 8, 10, and 12 months of age. Mothers were asked if the child experienced any episodes of fever and diarrhea in the previous two weeks and if the child had been ill in the last two months. At 4, 6, 8, and 12 months, mothers were asked about the types of food fed to the child, frequency of feeding their child, and number of meals the child ate on the previous day. Infant 24-hour dietary recalls were collected by trained local nutritionists using local, standard dishes and utensils to calculate quantities of food. These time points were chosen to reflect infant and young child feeding milestones within the first year of life and to reflect early introduction of complementary foods, which is a common practice in Egypt. Nutrient intakes were calculated using the Egyptian food composition table, developed by the National Nutrition Institute of Egypt. Program exposure level was divided into three categories–low, medium, and high–and was calculated for each visit starting at two months. Creation of the program exposure variable took into account receipt by mothers or their family members of various program elements offered at different time points. These elements included receipt of educational health and nutrition messages or attendance at specific counseling sessions during pregnancy and the postpartum period, for both mother and child.

Statistical analysis

Descriptive statistics by governorate were calculated as means or proportions. Differences by governorate (i.e., Lower Egypt and Upper Egypt), background characteristics, proportion of infants with reported morbidity or illness, nutrient intakes, and program exposure were tested using statistical models. Multivariate longitudinal mixed models were used to examine factors associated with the following measures of growth: weight-for-age Z-score (WAZ), length-for-age Z-score (LAZ), and weight-for-length Z-score (WLZ). This type of model allowed for accounting and controlling for variables previously identified in research studies to be associated with growth (e.g., maternal height) and for testing the associations of other variables (e.g., diarrhea or fever) with growth outcomes.

Models included data at 4, 6, 8, and 12 months of age, and controlled for sex, maternal height, parity, maternal education, and birth Z-score. The following predictors and variables were included in the models: governorate, study visit, diarrhea for seven days or longer, fever, and program exposure level. Dietary intake of kilocalories, vitamin A, total iron, total zinc, and calcium from complementary food, and number of food groups consumed during the previous 24 hours were also tested using statistical models.

We used Wald tests to test for interactions between all predictors and governorate to see if the level or pattern of the variables/predictors of growth differed by geographic area. To understand how declines in weight were related to stunting, we calculated declines in weight between adjacent study visits (e.g., two and four months) and then created an indicator variable for any weight loss during the study. Using logistic regression, the association between any weight loss and stunting at 12 months was examined, controlling for sex, maternal height, parity, maternal education, and LAZ at birth. Stata version 13.0 was used to conduct the statistical analysis.

KEY FINDINGS

Of 300 women enrolled in their third trimester of pregnancy, complete data were obtained for 295 mother-infant pairs. One infant died and four mother-infant pairs were lost to follow-up during the 12-month period of data collection. The analysis sample included 147 mother-infants pairs in Lower Egypt and 148 in Upper Egypt. Mothers in Upper Egypt were significantly older ($p<0.001$) and had less schooling ($p<0.01$). All mothers were married, and slightly less than half of infants were female.

Nutritional status and predictors of growth in Egyptian children

The proportion of infants who were underweight peaked at the age of 2 months (8% in Lower Egypt and 11% in Upper Egypt), but was generally low throughout the first year of life. There were significantly more underweight children in Upper Egypt (5%) than in Lower Egypt (1%) at 6 months of age. The proportion of infants who were stunted increased from 6-12 months of age in Lower Egypt, rising from 5% to 24%. In Upper Egypt, stunting peaked at 6 months (17%) and the pattern was less clear. There was variability in the proportion of stunted infants from 812 months in Upper Egypt, decreasing to 9% at 10 months and increasing to 13% at 12 months of age. In Lower Egypt, overweight steadily increased from 6 to 10 months of age, with nearly one-third of children overweight at 12 months of age. In Upper Egypt, overweight peaked at 8 months of age, with 18% of children overweight, and then decreased to 11% by 12 months of age. There were no significant differences noted between Upper and Lower Egypt in stunting or overweight at any study visit. Yet, growth patterns in this cohort of Egyptian infants indicated that LAZ decreased and WLZ increased from 6 to 12 months of age, culminating in a stunting prevalence of 25% and overweight prevalence of 30% at 12 months of age in Lower Egypt.

On average, infants had approximately one illness episode during the previous two months. Fever was quite common, especially from the four-month visit onward. For example, at 4 months of age 42% of infants in Lower Egypt and 45% in Upper Egypt reportedly had fever during the last two weeks. The proportion of infants with diarrhea for seven or more days peaked at 6 months of age in Upper Egypt (21%) and 8 months of age in Lower Egypt (22%).

Nearly all infants were breastfed throughout the study period, and there were no differences in the proportion breastfed by governorate. The mean number of food groups consumed in the previous 24 hours was higher in Upper than Lower Egypt at 4 and 12 months of age (4 months: Upper Egypt 0.7 ± 0.8, Lower Egypt 0.4 ± 0.7, $p<0.05$; 12 months: Upper Egypt 3.5 ± 1.2, Lower Egypt 3.0 ± 0.9, $p<0.05$). According to WHO, along with breastfeeding, starting at 6 months of age, children need dietary diversity, which includes eating foods from four or more of the following seven food groups: (1) grains, roots, and tubers; (2) legumes and nuts; (3) dairy products (milk, yogurt, cheese); (4) flesh foods (meat, fish poultry, liver/organ meats); (5) eggs; (6) vitamin A rich fruits and vegetables; and (7) other fruits and vegetables [2]. On average, at the ages of 6, 8, and 12 months, children were not receiving an adequate variety of foods, as reflected in mean number of food groups consumed.

As expected, dietary intakes from complementary foods were low at 4 months of age and increased to the end of the study, with the exception of vitamin A. Infants in Upper Egypt had higher energy intakes at 4 and 6 months of age than those in Lower Egypt (4 months: Upper Egypt 244.7 kcal, 95% CI [241.8, 247.7], Lower Egypt 233.5 kcal, 95% CI [226.8, 240.5], $p<0.01$; 6 months: Upper Egypt 544.9 kcal, 95% CI [519.6, 571.5], Lower Egypt 462.0 kcal, 95% CI [434.4, 491.4], $p<0.05$). Infants in Upper Egypt also had higher iron intakes at the age of 4 months (Upper Egypt 0.50 mg, 95% CI [0.50, 0.50]; Lower Egypt 0.48 mg, 95% CI [0.46, 0.50],

$p<0.01$) and higher iron (Upper Egypt 1.39 mg 95% CI [1.26, 1.54]; Lower Egypt 1.11 mg, 95% CI [1.02, 1.20], $p<0.05$) and zinc (Upper Egypt 2.3 mg, 95% CI [2.2, 2.4]; Lower Egypt 1.9 mg, 95% CI [1.8, 2.0], $p<0.01$) intakes at 6 months old than infants in Lower Egypt. Participants were exposed to more elements of the SMART project during the early visits, with exposure generally declining over time. However, the pattern of exposure to program elements differed by governorate at 8, 10, and 12 months of age, indicating that more participants in Upper Egypt than in Lower Egypt had high levels of exposure ($p<0.05$ at 8 months, $p<0.001$ at 10 and 12 months).

Association of governorate, morbidity, program exposure, and visit with infant growth

Compared to the four-month visit, all subsequent study visits were associated with higher WAZ and WLZ and with lower LAZ. Wald tests indicated that overall there were significant interactions between visit and governorate, showing that the slopes differed by governorate, for LAZ ($p<0.05$) and WLZ ($p<0.05$), but not for WAZ.
For LAZ, these patterns were detected: Lower Egypt (6 months -0.39 SD, 8 months -0.62 SD, 12 months -1.01 SD, all $p<0.001$) and Upper Egypt (6 months, -0.61 SD; 8 months, -0.71 SD; 12 months, -0.79 SD; all $p<0.001$).
For WLZ, the patterns by governorate were: Lower Egypt (6 months 0.48 SD, 8 months 0.95 SD, 12 months 1.30 SD, all $p<0.001$) and Upper Egypt (6 months, 0.75 SD; 8 months, 1.11 SD; 12 months, 1.09 SD; all $p<0.001$).
No interaction between governorate and diarrhea was detected and diarrhea was not associated with any growth outcome.

Association of dietary intake from complementary food with infant growth

Energy intake was associated with higher WAZ and LAZ (both $p<0.05$), and iron intake was associated with higher WAZ ($p<0.01$), following adjustment for infant sex, birth Z-score, maternal height, parity, and education. For WLZ, an interaction of iron with governorate was observed. Iron intake was associated with higher WLZ in Lower Egypt (0.33 SD, $p<0.01$), but not in Upper Egypt (0.07 SD, $p=0.47$). We found positive associations of energy intake with WAZ and LAZ and of iron intake with WAZ and WLZ (Lower Egypt only). Other factors, including diarrhea, fever, program exposure, and other measures of dietary intake, were not associated with any growth outcome.

Association of weight loss with stunting at 12 months

We observed a significant interaction of governorate and weight loss between any adjacent study visits ($p<0.05$). Weight loss at any time point in the first year of life was associated with a twofold greater odds of stunting at 12 months in Lower Egypt (OR 2.0, $p<0.05$), but no association was detected in Upper Egypt (OR 0.83, $p=0.59$).

CONCLUSIONS AND RECOMMENDATIONS

Energy and nutrient intakes were generally higher in Upper than Lower Egypt, whereas reported diarrhea prevalence was similar in both areas. This suggests that differences in diet quality, rather than variability in morbidity, may be a key factor in growth patterns in Upper versus Lower Egypt. Our recent operations research shows that Egyptian children < 2 years of age frequently consume energy-dense “junk” foods (i.e., high in fat, low in nutrients) in conjunction with a limited variety of small quantities of nutritious foods. Overall, children had inadequate intake of multiple nutrients, including energy, zinc, vitamin A, and iron, and junk foods comprised about 20% of energy intake from 6 to 11 months of age. Government subsidies of sugar and oil have permeated the Egyptian food base, which can also contribute to the problem of feeding low-nutrient, high-calorie foods.

In Egypt, the double burden of malnutrition, with static stunting rates and rising levels of overweight and obesity in children, has emerged as an escalating public health concern alongside a “nutrition transition,” typified by a growing reliance on energy-dense, low-in-nutritional-value foods and a shift away from traditional diets. A diet high in energy that provides excess calories may contribute to overweight, while at the same time lacking the micronutrients needed to prevent stunting. The association we detected between higher energy intake and higher WAZ is consistent with Egypt's stage in the nutrition transition and with dietary patterns in this age group. Timing of introduction of complementary foods also may have played a role in the progression of overweight in the first year of life. In Egypt, early introduction of junk foods (i.e., cakes and biscuits) and other foods defined locally as "age-appropriate" is a common cultural practice. Consuming a wide variety of food ensures that children meet nutrient requirements for healthy growth. We found that higher iron intake was associated with higher WAZ and WLZ, but not with LAZ. The association of iron with weight in our sample is likely explained by the strong correlation between iron and energy intake. Infants who had higher energy intake had higher WAZ and also had higher iron intake.

In this study, weight loss in any interval during the first year of life was associated with a twofold likelihood of a child being stunted by one year of age. This finding is consistent with research showing a relationship between WLZ and subsequent stunting. In Egypt, rates of wasting were low, while a notable proportion of children were stunted or overweight, and 25% of those who were stunted at 12 months of age were also overweight. Mechanisms governing growth are not well understood, although some evidence indicates linear growth may be regulated, in part, by initial body mass or fatness.

These data reveal that overweight and stunting begin in the first year of life among Egyptian infants and have implications for nutrition programs in Egypt. Poor nutrition early in life can negatively affect learning capacity, cognitive development, and work productivity and capacity. Inadequate nutrient intake can alter a child's physiology, resulting in low muscle mass and more efficient storage of fat, which lead to increased risk of obesity, cardiovascular disease, and diabetes later in life [3-5].

In Egypt, infant and young child nutrition programs should address the dual burden of malnutrition and should target prevention of both stunting and overweight by promoting dietary quality and addressing families' reliance on energy-dense, snack or junk foods. Educational materials based on culturally tailored messages developed from the stunting study (i.e., Trials of Improved Practices, or TIPs) on breastfeeding and complementary feeding need to be given to mothers and their families to improve quantity, quality, and frequency of meals, within the context of reducing junk food. Community-level strategies should prioritize educational messages that target mothers, fathers, grandmothers, community health care providers, and CDAs to not feed junk foods—including sugary, salty foods, and soft drinks—to children less than 2 years of age. Families should be advised that junk food is detrimental to the growth of children and the entire family's health and well-being.

Introduction

Linear growth in infancy and early childhood is critical to the attainment of human capital and economic development of a society [6]. Stunted children often become adults of small stature, with limited work productivity, and reduced lifetime wage earnings [7-9]. A number of factors, including diarrheal illness, febrile infections, breastfeeding practices, and dietary quantity and quality of complementary foods, are known to be associated with growth [10, 11]. The presence of these factors and their relative importance in influencing growth vary by setting and the child's age.

Stunting remains an important problem in Egypt, where approximately one-third of children < 5 years of age are affected [1, 12]. During the last several years, food prices and food insecurity have risen in Egypt as a consequence of successive crises, including the avian influenza epidemic (2006) and food, fuel, and financial crises (2007–2009) [13, 14]. An increase in the prevalence of stunting from 2005 to 2008 was documented in Lower Egypt [1, 15]. It coincided with the avian influenza outbreak, but whether it was related to the outbreak or due to other factors remains unclear. A similar increase in stunting prevalence did not occur in Upper Egypt during the same period.

The primary objective of this study was to determine whether there were differences in growth patterns and factors related to growth in Lower Egypt and Upper Egypt within the context of a U.S. government-funded maternal and child health integrated program. Our secondary objective was to examine the relationship between weight and length to ascertain if weight loss in any two-month interval contributes to stunting at 12 months of age.

METHODS

Study design and sites

From 2009 until 2014, the Maternal and Child Health Integrated Program (MCHIP) was the United States Agency for International Development (USAID) flagship project on maternal, newborn, and child health. The program focused on addressing the underlying causes of maternal, newborn, and child mortality. MCHIP carried out the SMART project (Community-based Initiatives for a Healthy Life) in Egypt to improve health service delivery and nutritional status through private-sector community development association clinics and community health workers. The project implemented a nutrition education and rehabilitation program at the community level to address childhood malnutrition using a positive deviance approach [16]. The study sites reflect two of six SMART project governorates and allowed for comparisons of infant and young child feeding practices and other related factors between regions with the highest (Lower Egypt) and lowest (Upper Egypt) levels of stunting according to the 2008 Egypt Demographic and Health Survey[1].

The two study sites were Qaliobia governorate in Lower Egypt and Sohag governorate in Upper Egypt. Qaliobia, in Lower Egypt, is a semi-urban region north of Cairo in the Egypt Delta, with an estimated population of 4.2 million. It is the top producer in the country of chicken and eggs, and 11% of the population are considered poor [17]. Sohag governorate, in Upper Egypt, is an agricultural rural region, and nearly half the population of 3.7 million is considered poor. Sohag produces sugar cane, grains, and clover for animal husbandry [17]. The sample of mother-infant pairs was drawn from SMART project sites, which included three villages in Lower Egypt and five villages in Upper Egypt.

Sample characteristics

The SMART project identified and mapped all pregnant women in project communities. SMART project volunteers notified community health workers (CHWs) of births by study participants in designated study catchment areas. All pregnant women in Lower and Upper Egypt study areas were recruited at SMART project community development association (CDA) private clinics during a two-month period (February and March) in 2013. Eligibility criteria for women to participate in the study included the following: ≥ 18 years or age, last trimester of pregnancy, participation in the SMART project, and residence in Kafr Shokr district, Qaliobia, Lower Egypt, or El-Maragha district, Sohag, Upper Egypt. During routine project home visits, SMART project CHWs obtained oral consent from women and their husbands for the participation of the mother-infant pairs. Data were collected from April 2013 to June 2014. Ethical approval for the study protocol was obtained from the Egyptian Society for Health Care and Development Research Ethics committee and the PATH Ethics Committee in the U.S.

Data collection

Anthropometric measurements. Weight and recumbent length were measured at 0 (birth), 2, 4, 6, 8, 10, and 12 months of age using SECA digital infant scales (0.1 kg increment) and plastic length boards (in duplicate, to nearest 0.1 cm) made to UNICEF specifications. An average of the length measurements was used in this analysis. With the exception of the birth visit, all measurements were conducted at private-sector CDA clinics as part of routine SMART project measurements. Birth measurements were taken by SMART project CHWs during routine project home visits within the first 36 hours after the birth of the infant, regardless of where the delivery took place.

Anthropometric Z-scores were calculated using the World Health Organization growth standard [18]. Underweight was defined as weight-for-age Z-score WAZ <-2 SD; stunting was defined as length-for-age Z-score LAZ <- 2 SD; wasting was defined as weight-for-length Z-score WLZ<-2 SD; and overweight was defined as weight-for-length Z-score WLZ > + 2 SD. Mother's height was measured two months after birth to the nearest 0.1 cm using tape measures fixed to the wall.

Maternal and sociodemographic characteristics. Maternal and socioeconomic characteristics were measured at two months postpartum during the first clinic visit using an administered questionnaire. Maternal education was divided into four categories (none, some primary or secondary, completed secondary, and post-secondary), which were collapsed to two categories (less than secondary or completed secondary or higher) for the analysis.

Child morbidity. During each clinic visit following each birth, study CHWs conducted interviews with study participants. Maternal report of child illness was collected at 2, 4, 6, 8, 10, and 12 months of age. Mothers were asked if the child experienced any episodes of fever and diarrhea in the previous two weeks and if the child had been ill in the last two months. A variable denoting whether infants had diarrhea for seven days or longer in the previous two weeks was used in the analysis.

Child dietary intake. At the four-, six-, eight-, and twelve-month visits, mothers were asked about the types of food they fed their child, frequency of feeding their child, and number of meals the child ate on the previous day. Infant 24-hour dietary recalls were collected by trained local nutritionists using local, standard dishes and utensils to calculate quantities of food. These time points were chosen to reflect infant and young child feeding milestones within the first year of life and to reflect early introduction of complementary foods, which is a common practice in Egypt. Nutrient intakes were calculated using the Egyptian food composition table, developed by the National Nutrition Institute of Egypt. Recipes for local dishes were included in the Egyptian food composition tables.

Program exposure to SMART. Program exposure level was divided into three categories—low, medium, and high—and was calculated for each visit starting at two months. Creation of the program exposure variable took into account receipt by mothers or their family members of various program elements offered at different time points. At two months, low exposure was defined as exposure to 0–5 elements, medium as exposure to 6–10 elements, and high as exposure to 11–15 elements. At four months, low exposure was defined as exposure to 0–2 elements, medium as exposure to 3–5 elements, and high as exposure to 6–8 elements. From six months to 12 months, low exposure was defined as exposure to 0–3 elements, medium as exposure to 4–6 elements, and high as exposure to 7–9 elements. At two months, these elements included the receipt of the following educational messages or attendance at specific counseling sessions during pregnancy: weekly counseling session on what to expect during the first pregnancy, monthly session on good nutrition during pregnancy, awareness of danger signs during pregnancy, receipt of iron pills, message on importance of iron pills to avoid anemia, and message on plan for childbirth were given throughout pregnancy, as well as a message on the mother and her baby's health after delivery. In bimonthly visits from 2 to 12 months mothers were asked about messages received during pregnancy and about the baby's health seven days after delivery (during two-month visit only), as well as whether they received a medical examination, whether their husband/mother-in-law attended any awareness session, whether a CHW weighed and took the length of the child in the last two months, and whether they received messages on feeding when sick, care of the child when sick, family planning, and hand washing. During the 6-12 months visits at six, eight, ten, and 12 months postpartum, mothers were asked if they received messages on feeding their children foods starting at 6 months of age.

Statistical analysis

Descriptive statistics by governorate were calculated as means or proportions. Differences by governorate (i.e., Lower Egypt and Upper Egypt), background characteristics, proportion of infants with reported morbidity or illness, nutrient intakes, and program exposure were tested using statistical models. In this analysis, simple regression models were used to compare descriptive data in Upper and Lower Egypt. These statistical models accounted for clustering at the village level. Nutrient intakes followed non-Gaussian (i.e., not normal, bell-shaped) distributions and were log transformed before being included in our statistical models (i.e., regression analysis).

Multivariate longitudinal mixed models were used to examine factors associated with the following measures of growth: weight–for-age Z-score (WAZ), length–for-age Z-score (LAZ), and weight-for-length Z-score (WLZ). Multivariate mixed models are a method of analysis for measuring the associations of governorate and other factors / predictors of infant growth. This type of model allows us to control and account for variables identified in previous studies that are associated with growth (e.g., maternal height) and to test associations of these variables (e.g., diarrhea or fever) with growth outcomes. A mixed model also accounts for multiple levels of clustering, including repeated measurements of the same infants over time and for the fact that these infants live in villages with their families, where their individual characteristics are likely grouped or clustered together.

Models included data at 4, 6, 8, and 12 months of age, and controlled for sex, maternal height, parity, maternal education, and birth Z-score. The following predictors or variables were included in the models: governorate, study visit, diarrhea for seven days or longer, fever, and program exposure level. Dietary intake of kilocalories, vitamin A, total iron, total zinc, and calcium from complementary foods, and number of food groups consumed during the previous 24 hours were included in separate models.

We tested for interactions between all predictors and governorate to see if the level or pattern of the variables/predictors of growth differed by geographic area. In some cases, we found a significant interaction of a predictor with governorate, but no significant association of the predictor with the growth outcome. This means that the pattern or slope of the variable differed in Upper and Lower Egypt, but that the variable was not related to growth. For significant interactions of categorical variables (such as visit) and governorate, Wald tests were used to determine statistical significance of the interaction. Tests for interactions were considered significant at $p < 0.10$; tests of association were significant at $p < 0.05$.

To understand how declines in weight were related to stunting, we calculated declines in weight between adjacent study visits (e.g., at 2 and 4 months of age) and then created an indicator variable for any weight loss during the study. Using logistic regression accounting for clustering at the village level, the association between any weight loss and stunting at 12 months was examined, while controlling for sex, maternal height, parity, maternal education, and LAZ at birth. We also tested for an interaction between weight loss and governorate. Stata 13.0 was used to conduct the statistical analyses.

RESULTS

Study participants

Of 300 enrolled women in their third trimester of pregnancy, complete data were obtained for 295 mother-infant pairs. One infant died and four mother-infant pairs were lost to follow-up during the 12-month period of data collection. The analysis sample included 147 mother-infants pairs in Lower Egypt and 148 in Upper Egypt. Mothers in Upper Egypt were significantly older ($p < 0.001$) and had less schooling ($p < 0.01$) (**Table 1**). All mothers were married and slightly less than half of the infants were female.

Nutritional status and predictors of growth in Egyptian children

The proportion of infants who were underweight peaked at age 2 months (8% in Lower Egypt, and 11% in Upper Egypt), but was generally low throughout the first year of life (**Table 2**). There were significantly more underweight children in Upper Egypt (5%) than Lower Egypt (1%) at 6 months of age. Wasting followed the same pattern as underweight, peaking at 2 months of age, when more than three times as many infants were wasted in Upper Egypt (18%) than Lower Egypt (5%). There were significantly more wasted infants in Upper Egypt at two time points: at 2 months ($p<0.001$) and 6 months of age ($p<0.05$). The proportion of infants in Lower Egypt who were stunted increased from 6-12 months of age, rising from 5% to 24%. In Upper Egypt, stunting peaked at 6 months of age (17%), and the pattern was less clear. There was variability in the proportion of stunted infants between 8 and12 months of age in Upper Egypt, with a decrease to 9% at 10 months and an increase to 13% at 12 months. In Lower Egypt, overweight steadily rose between 6 and 10 months of age, with nearly one-third of children overweight at 12 months of age. In Upper Egypt, overweight peaked at 8 months of age, with 18% of children overweight, and then decreased to 11% at 12 months of age. There were no significant differences between Upper and Lower Egypt in stunting or overweight at any study visit.

On average, infants had approximately one illness episode during the previous two months. Fever was quite common, especially from the four-month visit onward (**Table 3**). For example, at 4 months of age 42% of infants in Lower Egypt and 45% in Upper Egypt reportedly had fever during the last two weeks. The proportion of infants with diarrhea for seven days or more peaked at 6 months in Upper Egypt (21%) and 8 months in Lower Egypt (22%). At 2 months of age a greater proportion of infants in Upper than in Lower Egypt had diarrhea for seven days or more (Upper 23%, Lower 10%, $p<0.05$) and fever (Upper 35%, Lower 21%, $p<0.01$). No differences were detected by governorate at other study visits.

Nearly all infants were breastfed throughout the study period and there were no differences by governorate in the proportion breastfed (Table 4). The mean number of food groups consumed in the previous 24 hours was higher in Upper than Lower Egypt at 4 and 12 months of age (4 months: Upper 0.7 ± 0.8, Lower 0.4 ± 0.7, p<0.05; 12 months: Upper 3.5 ± 1.2, Lower 3.0 ± 0.9, p<0.05).

Mean number of meals consumed was higher in Upper Egypt than Lower Egypt at all time points, though significantly different at 6 months of age (1.5 + 0.9 meals for Lower Egypt, 2.0 + 1.5 meals for Upper Egypt). According to WHO, mothers should feed children 6–8 months of age at least two meals per day if they are breastfed and one to two cups of milk and one to two extra meals per day if they are not breastfed, per minimum meal frequency recommendations [19]. For children 9–11 months of age, WHO recommends feeding breastfed children at least three meals per day, ; non-breastfed children should receive one to two cups of milk and one to two extra meals per day[19]. Since the majority of children are breastfed, as indicated in these data, the recommendations for breastfeeding are most applicable in this context. Table 4 also reveals that few children had a minimum acceptable diet[1] at ages 6 and 8 months. However, this indicator had improved by age 12 months, as the number of food groups (diversity) and the number of meals increased.

As expected, dietary intake from complementary foods was low at 4 months of age and increased by the end of the study, with the exception of vitamin A (**Table 5**). Infants in Upper Egypt had higher energy intakes at 4 and 6 months of age than those in Lower Egypt (4 months: Upper Egypt 244.7 kcal, 95% CI (241.8, 247.7), Lower Egypt 233.5 kcal, 95% CI (226.8, 240.5), $p<0.01$; 6 months: Upper Egypt 544.9 kcal, 95% CI (519.6, 571.5), Lower Egypt 462.0 kcal, 95% CI (434.4, 491.4), $p<0.05$). Infants in Upper Egypt also had higher iron intake at 4 months of age (Upper Egypt 0.50 mg, 95% CI [0.50, 0.50]; Lower Egypt 0.48 mg, 95% CI [0.46, 0.50], $p<0.01$) and higher iron (Upper Egypt 1.39 mg, 95% CI [1.26, 1.54]; Lower Egypt 1.11 mg, 95% CI [1.02, 1.20], $p<0.05$) and zinc intakes at 6 months (Upper Egypt 2.3 mg, 95% CI [2.2, 2.4]; Lower Egypt 1.9 mg, 95% CI [1.8, 2.0], $p<0.01$) than infants in Lower Egypt.

Participants were exposed to more elements of the SMART project during the early visits, with exposure generally declining over time (**Table 6**). Some participants in Upper Egypt had greater exposure to some individual program elements than those in Lower Egypt (data not shown). For example, child weight and height were more frequently measured at 4, 6, 8, and 10 months of age (all visits, $p<0.05$) as part of the SMART project in Upper Egypt than Lower Egypt. However, the pattern of exposure to program elements differed by governorate at 8, 10, and 12 months of age, indicating that more participants in Upper Egypt than in Lower Egypt had high levels of exposure ($p<0.05$ at 8 months, $p<0.001$ at 10 and 12 months).

Association of governorate, morbidity, program exposure, and visit with infant growth

As compared to the four-month visit, all subsequent study visits were associated with higher WAZ and WLZ and with lower LAZ (**Table 7a**). Wald tests indicated that overall there were

[1] Minimum acceptable diet of breastfed children 6–23 months of age is defined as the proportion of breastfed children who had at least the minimum dietary diversity and the minimum meal frequency during the previous day. Minimum dietary diversity of children 6–23 months of age is the proportion of children who receive foods from four or more food groups. According to WHO, minimum dietary diversity includes eating foods from four or more of the seven food groups: (1) grains, roots, and tubers; (2) legumes and nuts; (3) dairy products (milk, yogurt, and cheese); (4) flesh foods (meat, fish poultry, and liver/organ meats); (5) eggs; (6) vitamin A rich fruits and vegetables; and (7) other fruits and vegetables.

significant interactions between visit and governorate, showing that the slopes differed by governorate for LAZ ($p<0.05$) and WLZ ($p<0.05$), but not for WAZ. For LAZ, the following patterns were detected: Lower Egypt (6 months -0.39 SD, 8 months -0.62 SD, 12 months -1.01 SD; all $p<0.001$) and Upper Egypt (6 months -0.61 SD, 8 months -0.71 SD, 12 months -0.79 SD, all $p<0.001$). For WLZ, the patterns by governorate were as follows: Lower Egypt (6 months 0.48 SD, 8 months 0.95 SD, 12 months 1.30 SD; all $p<0.001$) and Upper Egypt (6 months 0.75 SD, 8 months 1.11 SD, 12 months 1.09 SD; all $p<0.001$). The predicted patterns of growth based on the models are shown in **Figure 1**.

We observed significant interactions of governorate with fever for WAZ and WLZ and of governorate with program exposure for LAZ and WLZ. However, further examination of the interactions revealed that there were no significant main effects of governorate, fever, or program exposure with WAZ, LAZ, or WLZ in either governorate (**Table 7a**). No interaction between governorate and diarrhea was detected and diarrhea was not associated with any growth outcome.

Association between dietary intake from complementary food and infant growth

Energy intake was associated with higher WAZ and LAZ (both $p<0.05$), and iron intake was associated with higher WAZ ($p<0.01$), following adjustment for infant sex, birth Z-score, and maternal height, parity, and education (**Table 7b**) For WLZ, an interaction of iron with governorate was observed. Iron intake was associated with higher WLZ in Lower Egypt (0.33 SD, $p<0.01$) but not in Upper Egypt (0.07 SD, $p=0.47$). We found no association between other dietary intake variables (vitamin A, zinc, calcium, or consumption of three or more foods groups) and any growth outcome.

Association of weight loss with stunting at 12 months of age

We observed a significant interaction of governorate with weight loss between any adjacent study visits ($p<0.05$) (**Table 8**). Weight loss at any time point in the first year of life was associated with a greater odds of stunting at 12 months of age in Lower Egypt (OR 2.0, $p<0.05$), but no association was detected in Upper Egypt (OR 0.83, $p=0.59$).

DISCUSSION

Growth patterns in this cohort of Egyptian infants indicate that LAZ decreased and WLZ increased from 6-12 months of age. The slopes for both outcomes were steeper in Lower Egypt than in Upper Egypt, culminating in stunting prevalence of 25% and overweight prevalence of 30% at 12 months of age in Lower Egypt. We found positive associations of energy intake with WAZ and LAZ and between iron intake and WAZ and WLZ (Lower Egypt only). Other factors, including diarrhea, fever, program exposure, and other measures of dietary intake, were not associated with any growth outcome. Weight loss during any time point in the first year of life was associated with greater odds of stunting at 12 months of age in Lower Egypt, but not in Upper Egypt.

Energy and nutrient intakes were generally higher in Upper Egypt than in Lower Egypt, whereas reported diarrhea prevalence was similar in the two areas. This suggests that differences in diet quality, rather than variability in morbidity, may be a key factor in growth patterns in Upper versus Lower Egypt. Our recent operations research shows that Egyptian children less than 2 years of age frequently consume energy-dense junk foods (i.e., foods high in fat and low in nutrients) in conjunction with a limited variety and small quantities of nutritious foods [20, 21]. Overall, children had inadequate intake of multiple nutrients, including energy, zinc, vitamin A, and iron; and junk foods comprised about 20% of energy intake among infants 6–11 months of age [20, 21]. Government subsidies of sugar and oil have permeated the

Egyptian food base, which can also contribute to the problem of feeding low-nutrient, high-calorie foods [22-25].

In Egypt, the double burden of malnutrition, with static stunting rates and rising levels of overweight and obesity in children [1, 12], is an escalating public health concern alongside a "nutrition transition," typified by a growing reliance on energy-dense, low-in-nutritional value foods and a shift away from traditional diets [13, 26, 27]. Countries in the midst of the nutrition transition have found the dual burden of malnutrition within the same household [28]. A stunted child and an overweight mother in the same home has been documented with higher frequency (>10% of households) in Egypt and several Latin American countries than in other countries that have not yet experienced the depth or extent of this phenomenon [28]. In comparison with normal and non-obese households, child consumption of sugary snack foods is associated with 51% higher likelihood of being part of a household with a stunted child and an obese mother [29]. A diet high in energy that provides excess calories may contribute to overweight while at the same time lacking the micronutrients needed to prevent stunting [6]. The association we detected between higher energy intake and higher WAZ is consistent with Egypt's stage in the nutrition transition and with dietary patterns in this age group. The timing of introduction of complementary foods also may have played a role in the progression of overweight in the first year of life. In Egypt, early introduction of junk foods (e.g., cakes and biscuits) and other foods defined locally as "age-appropriate" is a common cultural practice [21]. Evidence from another setting indicates that infants who received foods prior to 16 weeks of age had significantly higher weight gain in the first year of life than children who started eating food later (> 16 weeks) [30].

Consuming a wide variety of food ensures that children meet nutrients requirements for healthy growth [10, 31]. We found that higher iron intake was associated with higher WAZ and WLZ, but not with LAZ. The association of iron with weight in our sample is likely explained by the strong correlation between iron and energy intake. Infants who had higher energy intake had higher WAZ and also had higher iron intake. There have been mixed findings on the relationship of heme iron, found in animal source foods, and linear growth. Positive associations have been detected in cross-sectional studies [32, 33], but a large multi-country trial found that infants and young children who were given animal source foods between 6 and 18 months of age did not have improved linear growth [34].

In this study, weight loss in any interval during the first year of life was associated with a twofold likelihood of a child being stunted by one year of age. This finding is consistent with research showing a relationship between WLZ and subsequent stunting [35] [36]. In Egypt, rates of wasting were low, while a notable proportion of children were stunted or overweight and 25% of those who were stunted at 12 months of age were also overweight. Mechanisms governing growth are not well understood, some evidence indicates linear growth may be regulated in part by initial body mass or fatness [35]. Stunting and wasting have been described as distinct processes, which respond to stressors in different ways and are dependent on the timing and severity of the stressors [37]. It also has been hypothesized that minimal or "marginal" insults will result in loss in length while weight-for-length is conserved [38].

Limitations

This study had several limitations. First, the study sample was limited to 300 pregnancies that occurred in the study areas, all of which were included in the study. Although every mother in late pregnancy in our study areas was enrolled, a larger sample size may have aided in our ability to detect associations between growth, nutrient intake, and illness, as well as program exposure. Second, our study focused on the period of infancy, in the first 12 months of life, while stunting peaks at 18–23 months of age in Egypt, where relationships with factors related to growth may be more pronounced [1]. Third, infants were reported to be ill frequently, yet there was no association of diarrhea or fever with any growth outcomes. Negative associations between diarrhea and weight in the short term and length in the long term are well established [39] , and diarrhea has previously been associated with linear growth faltering in Egyptian children [40] . The lack of association of illness with growth in this study may reflect the inability to capture severity of illness by maternal interview. Maternal perceptions of what is considered as diarrhea may not be consistent with biomedical definitions of the condition [41-44].

CONCLUSION

These data reveal that overweight and stunting begin in the first year of life among Egyptian infants and have implications for nutrition programs in Egypt. Poor nutrition early in life can negatively impact learning capacity, cognitive development, and work productivity and capacity [6-8] . Inadequate nutrient intake can alter a child's physiology, resulting in low muscle mass and more efficient storage of fat, which leads to an increased risk of obesity, cardiovascular disease, and diabetes later in life [3, 4].

In Egypt, infant and young child nutrition programs should address the dual burden of malnutrition and target the prevention of both stunting and overweight by promoting dietary quality and addressing families' reliance on energy-dense snack or junk foods. Educational materials, based on culturally tailored messages developed from the stunting study (i.e., Trials of Improved Practices, or TIPs) on breastfeeding and complementary feeding need to be given to mothers and their families to improve the quantity, quality, and frequency of meals within the context of reducing junk food. In addition, given that stunting peaks at 18–23 months in Egyptian children and our conclusions are limited to the first 12 months of life, continued follow-up of the children enrolled in this study, through 24 months of age, would aid in better understanding factors associated with growth in the first two years of life.

Community-level strategies should prioritize educational messages that target mothers, fathers, grandmothers, community health care providers, and CDAs to not feed junk foods—including sugary, salty foods, and soft drinks—to children less than two years old. Families should be advised that junk food is detrimental to children's growth and the entire family's health and well-being.

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Table 1: Characteristics of mothers and infants in Lower and Upper Egypt

CHARACTERISTIC	LOWER (N=147)	UPPER (N=148)
Mother		
Age at delivery	25.4 ± 4.3	27.2 ± 5.7***
Height at 2 months post-partum	159.3 ± 6.8	158.6 ± 5.0
Parity	1.1 ± 1.2	1.7 ± 1.7**
Education None or some primary/secondary Completed secondary or higher	 24% (34) 76% (103)	 40% (59) 60% (89)***
Married	100% (147)	100% (148)
Infant's sex Female Male	 46% (68) 54% (79)	 48% (71) 52% (77)

*p<0.05, **p<0.01, ***p<0.001

Significance determined using logistic regression for categorical variables and linear regression for continuous variables. All models adjusted for clustering at the village level. For maternal education, the regression model used two categories – less than secondary completed and completed secondary or higher.

Table 2: Percentage of infants underweight, stunted, wasted, and overweight in Lower and Upper Egypt

	UNDERWEIGHT (WAZ≤2)		STUNTED (LAZ≤2)		WASTED (WLZ≤2)		OVERWEIGHT (WLZ>2)	
	Lower % (n)	Upper % (n)	Lower % (n)	Upper % (n)	Lower % (n)	Upper % (n)	Lower % (n)	Upper % (n)
Birth	3 (4)	2 (3)	8 (12)	9 (13)	10 (14)	13 (19)	13 (19)	10 (15)
2 months	8 (11)	11 (15)	7 (10)	4 (5)	5 (7)	18 (25)***	7 (10)	4 (5)
4 months	3 (4)	8 (11)	6 (9)	4 (5)	6 (8)	9 (12)	6 (9)	2 (3)
6 months	1 (1)	5 (7)*	5 (7)	17 (24)	1 (1)	4 (6)*	10 (14)	15 (22)
8 months	0 (0)	5 (7)	12 (17)	15 (21)	1 (1)	2 (3)	19 (27)	18 (25)
10 months	0 (0)	3 (4)	13 (17)	9 (13)	0 (0)	2 (3)	31 (42)	14 (20)
12 months	0 (0)	4 (6)	24 (33)	13 (18)	0 (0)	1 (1)	30 (42)	11 (15)

*p<0.05, **p<0.01, ***p<0.001; significance determined using logistic regression adjusted for clustering at the village level.

Figure 1: WAZ, LAZ, and WLZ in infants in Upper and Lower Egypt (based on models of factors related to growth)

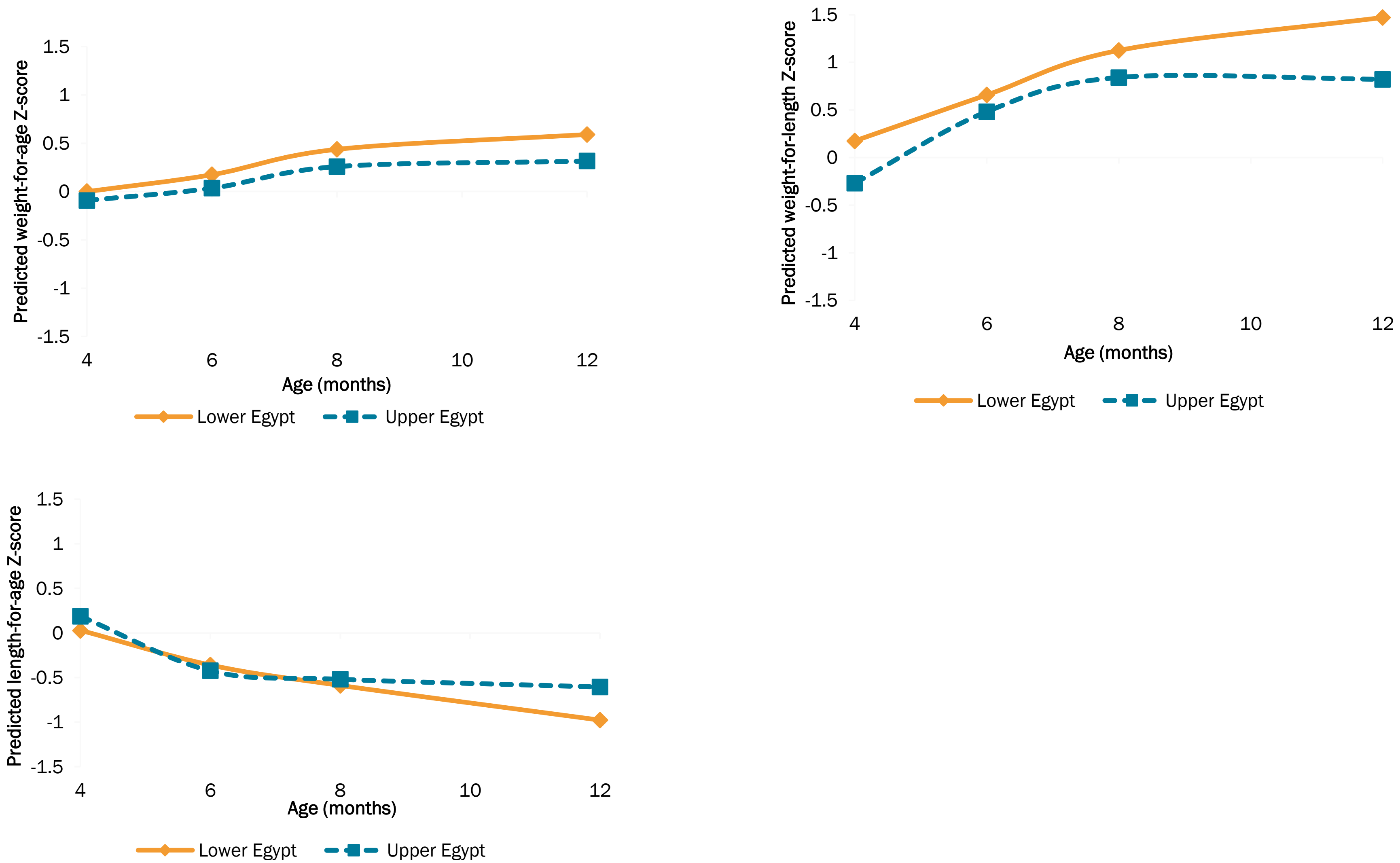

Table 3: Percentage of infants with common illness symptoms in the last two weeks in Lower and Upper Egypt

	2 MONTHS		4 MONTHS		6 MONTHS		8 MONTHS		10 MONTHS		12 MONTHS	
	Lower (n=145)	Upper (n=142)	Lower (n-142)	Upper (n=141)	Lower (n=142)	Upper (n=142)	Lower (n=139)	Upper (n=139)	Lower (n=124)	Upper (n=140)	Lower (n=139)	Upper (n=140)
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
Diarrhea[a]	10 (15)	23 (32)*	16 (23)	16 (23)	20 (29)	21 (30)	22 (30)	11 (15)	13(18)	14 (20)	12 (17)	13 (18)
Fever	21 (30)	35 (49)**	42 (59)	45 (63)	50 (71)	51 (72)	47 (66)	54 (75)	45 (56)	50 (70)	40 (56)	52 (73)

*p<0.05, **p<0.01, ***p<0.001; significance determined using logistic regression adjusted for clustering at the village level.

[a] Diarrhea = seven days or more days of diarrhea in last two weeks.

Table 4: Infant feeding practices in Lower and Upper Egypt

	2 MONTHS		4 MONTHS		6 MONTHS		8 MONTHS		10 MONTHS		12 MONTHS	
	Lower (n=145)	Upper (n=142)	Lower (n-142)	Upper (n=141)	Lower (n=142)	Upper (n=142)	Lower (n=139)	Upper (n=139)	Lower (n=124)	Upper (n=140)	Lower (n=139)	Upper (n=140)
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
% breast-feeding	97 (142)	96 (137)	96 (137)	97 (137)	96 (136)	95 (135)	96 (133)	94 (131)	94 (128)	94 (131)	94 (131)	90 (126)
Mean # of food groups eaten in last 24h	-	-	0.4 ± 0.7	0.7 ± 0.8*	1.4 ± 0.8	1.5 ± 1.0	2.3 ± 0.9	2.5 ± 1.1	-	-	3.0 ± 0.9	3.5 ± 1.2*
Mean # of meals consumed in last 24h	-	-	0.4 ± 0.7	1.1 ± 1.5^	1.5 ± 0.9	2.0 ± 1.5*	2.5 ± 1.2	3.1 ± 1.5	-	-	3.0 ± 0.9	3.9 ± 1.7
% of infants with minimum acceptable diet	-	-	-	-	2 (3)	6 (9)	7 (10)	19 (27)**	-	-	68 (94)	64 (89)

*p<0.05, **p<0.01, ***p<0.001; significance determined using logistic regression for categorical variables and linear regression for continuous variables; all models adjusted for clustering at the village level. According to WHO, minimum dietary diversity includes eating foods from four or more of the seven food groups: (1) grains, roots, and tubers; (2) legumes and nuts; (3) dairy products (milk, yogurt, and cheese); (4) flesh foods (meat, fish poultry, and liver/organ meats); (5) eggs; (6) vitamin A rich fruits and vegetables; and (7) other fruits and vegetables. According to WHO, minimum meal frequency for children 6–8 months of age means at least two meals per day for breastfed children and for children 9–11 months of age at least three meals per day for breastfed children. Minimum acceptable diet for breastfed children 6–23 months of age is defined as at least the minimum dietary diversity and the minimum meal frequency during the previous day.

Table 5: Geometric mean (95% CI) nutrient intake from complementary food among children in Lower and Upper Egypt at 4, 6, 8, and 12 months of age

NUTRIENT	4 MONTHS		6 MONTHS		8 MONTHS		12 MONTHS	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Energy (kcal)	233.5 (226.8, 240.5)	244.7** (241.8, 247.7)	462.0 (434.4, 491.4)	544.9* (519.6, 571.5)	578.3 (560.5, 596.7)	620.4 (593.9, 648.0)	708.4 (675.9, 742.5)	814.3 (769.7, 861.4)
Calcium (mg)	162.8 (148.7, 178.3)	173.5 (171.8, 175.3)	203.7 (190.1, 218.3)	212.4 (207.1, 218.0)	300.4 (285.2, 316.4)	328.1 (309.0, 348.3)	338.9 (317.7, 361.5)	459.7 (426.3, 495.7)
Total iron (mg)	0.48 (0.46, 0.50)	0.50*** (0.50, 0.50)	1.11 (1.02, 1.20)	1.39* (1.26, 1.54)	1.94 (1.77, 2.11)	2.10 (1.92, 2.30)	2.72 (2.50, 2.97)	3.57 (3.25, 3.93)
Total zinc (mg)	3.5 (3.4, 3.5)	3.4 (3.3, 3.5)	1.9 (1.8. 2.0)	2.3** (2.2, 2.4)	4.1 (4.0, 4.3)	4.0 (3.8, 4.2)	5.0 (4.8, 5.2)	5.1 (4.9, 5.3)
Vitamin A (RE)	520.9 (520.9, 520.9)	501.8 (479.6, 524.9)	473.0 (410.1, 545.5)	572.0 (547.0, 598.1)	541.2 (506.7, 578.0)	475.4 (425.4, 531.2)	471.7 (442.0, 503.3)	477.8 (446.5, 511.4)

*p<0.05, **p<0.01, ***p<0.001; significance determined on log-transformed variables using regression models adjusted for clustering at the village level.

Table 6: Percentage of participants with low, medium, or high exposure to SMART program elements in Lower and Upper Egypt (2–12 months)

	2 MONTHS		4 MONTHS		6 MONTHS		8 MONTHS*		10 MONTHS***		12 MONTHS***	
	Lower (n=145)	Upper (n=142)	Lower (n-142)	Upper (n=141)	Lower (n=142)	Upper (n=142)	Lower (n=139)	Upper (n=139)	Lower (n=124)	Upper (n=140)	Lower (n=139)	Upper (n=140)
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
Low	32 (46)	30 (42)	39 (56)	34 (48)	59 (83)	56 (80)	69 (96)	75 (105)	69 (93)	51 (71)	66 (92)	76 (107)
Medium	47 (69)	40 (58)	39 (55)	39 (55)	32 (46)	33 (46)	12 (16)	17 (23)	13 (17)	44 (62)	17 (24)	24 (33)
High	21 (30)	30 (42)	22 (31)	27 (38)	9 (13)	11 (16)	19 (27)	8 (11)	18 (25)	5 (7)	17 (23)	0 (0)

*p<0.05, **p<0.01, ***p<0.001. At 2 months of age, low=exposure to 0–5 elements, medium=exposure to 6–10 elements, and high=exposure to 11–15 elements. At 4 months, low=exposure to 0–2 elements, medium=exposure to 3–5 elements, high=exposure to 6–8 elements. From 6 to 12 months of age, low=exposure to 0–3 elements, medium=exposure to 4–6 elements, and high=exposure to 7–9 elements.

Table 7a: Factors associated with infant growth in Upper and Lower Egypt

	WAZ (N=281)			LAZ (N=281)			WLZ (N=277)		
	β	95% CI	P-value	β	95% CI	P-value	β	95% CI	P-value
Governorate	-0.02	-0.39, 0.34	0.907	0.27	-0.36, 0.91	0.403	-0.47	-1.11, 0.16	0.145
Diarrhea ≥ 7 days	-0.08	-0.20, 0.04	0.201	0.06	-0.10, 0.22	0.459	-0.10	-0.28, 0.07	0.241
Fever	0.09	-0.03, 0.21	0.152	0.01	-0.10, 0.13	0.831	0.13	-0.04, 0.30	0.135
Fever*gov	-0.15	-0.32, 0.03	**0.098**	-	-	-	-0.31	-0.56, -0.06	**0.015**
Program exposure									
Medium	-0.03	-0.15, 0.08	0.579	0.12	-0.11, 0.35	0.318	-0.22	-0.47, 0.03	0.090
High	-0.01	-0.21, 0.18	0.904	0.03	-0.33, 0.40	0.861	-0.29	-0.69, 0.10	0.143
Program exp*gov									
Medium	-	-	-	-0.28	-0.59, 0.03	**0.080**	0.32	-0.02, 0.66	**0.063**
High	-	-	-	0.03	-0.33, 0.40	0.861	0.66	0.10, 1.22	**0.021**
Visit (ref-4 mo)									
6 months	0.17	0.03, 0.32	**0.019**	-0.39	-0.59, -0.19	**<0.001**	0.48	0.26, 0.70	**<0.001**
8 months	0.44	0.29, 0.59	**<0.001**	-0.62	-0.82, -0.42	**<0.001**	0.95	0.72, 1.18	**<0.001**
12 months	0.59	0.44, 0.74	**<0.001**	-1.01	-1.21, -0.80	**<0.001**	1.30	1.07, 1.52	**<0.001**
Visit*gov (ref-4 mo)									
6 months	-0.05	-0.25, 0.16	0.650	-0.22	-0.51, 0.06	0.129	0.27	-0.05, 0.58	**0.098**
8 months	-0.09	-0.30, 0.12	0.422	-0.09	-0.39, 0.21	0.459	0.16	-0.18, 0.49	0.354
12 months	-0.18	-0.40, 0.03	**0.098**	0.22	-0.10, 0.53	0.175	-0.21	-0.54, 0.13	0.230

Results obtained using longitudinal mixed models including 4, 6, 8, and 12 months and accounting for clustering at the village and individual levels. Governorate uses Lower Egypt as the reference. Models control for infant sex and birth Z-score, maternal height, parity, and education.

Table 7b: Association of dietary intake from complementary food and growth in Upper and Lower Egypt

	WAZ (N=281)			LAZ (N=281)			WLZ (N=277)		
	β	95% CI	P-value	β	95% CI	P-value	B	95% CI	P-value
Energy	0.19	0.02, 0.36	**0.030**	0.23	0.01, 0.45	**0.042**	0.03	-0.21, 0.28	0.801
Vitamin A	-0.06	-0.16, 0.04	0.253	-0.03	-0.16, 0.10	0.615	-0.05	-0.19, 0.09	0.510
Total iron	0.13	0.04, 0.23	**0.006**	0.03	-0.10, 0.15	0.641	0.33	0.13, 0.53	**0.002**
Total iron*gov	-	-	-	-	-	-	-0.26	-0.54, 0.01	**0.061**
Total zinc	-0.15	-0.32, 0.02	0.084	-0.16	-0.39, 0.06	0.148	-0.07	-0.31, 0.17	0.577
Calcium	0.07	-0.05, 0.18	0.262	-0.02	-0.18, 0.13	0.783	0.06	-0.11, 0.23	0.490
3 or more food groups consumed	0.10	-0.03, 0.23	0.139	-0.02	-0.20, 0.15	0.763	0.14	-0.05, 0.34	0.155

Results obtained using longitudinal mixed models including 4, 6, 8, and 12 months and accounting for clustering at the village and individual levels. Governorate uses Lower Egypt as the reference. Models control for infant sex and birth z-score, maternal height, parity, and education. We used separate models that included covariates from Table 7a to study associations of each dietary variable with growth outcomes.

Table 8: Association between weight loss during any two-month interval and stunting at 12 months of age in Egyptian children

FACTORS	STUNTED AT 12 MONTHS OF AGE		
	Odds Ratio	95% CI	P-value
Weight loss in any two-month period	2.04	1.11, 3.76	**0.022**
Governorate (ref: Lower Egypt)	0.57	0.10, 3.29	0.53
Weight loss in any two month period * governorate	0.41	0.18, 0.93	**0.033**

Results obtained using a linear regression model accounting for clustering at the village level and controlling for infant sex, LAZ at birth, maternal height, parity, and education. Governorate uses Lower Egypt as the reference.