Ethnic Expansions and Between-Group Differences in Children's Health: A Case Study From the Rukwa Valley, Tanzania

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ABSTRACT The Sukuma ethnic group appears to be expanding across Tanzania at a rate far greater than other ethnic groups in the area. In this paper, the household-level dynamics that may be fueling this expansion are explored by comparing measures of infant mortality and child health with another Tanzanian ethnic group, the Pimbwe. Consistent with expectations, the Sukuma appear to have comparable levels of fertility but lower child mortality. As predicted, compared to the Pimbwe, Sukuma children are also heavier and taller for their age, suggesting better nutritional status. Four hypotheses about why the Sukuma are so successful in this area are addressed. Surprisingly, the results show that household food security and wealth are not related to children's nutritional status, nor can maternal effects account for the observed health differences. Several lines of evidence suggest that different patterns of infant feeding practices may underlie the differences in children's nutritional status. Am J Phys Anthropol 128:682–692, 2005.

The Sukuma have been expanding throughout Tanzania since at least the 1950s, and are now the most populous ethnic group in Tanzania (Brandström, 1990; Galaty, 1988). This demographic expansion has been continually reinforced by what Brandström (1990) called the Sukuma's "culture of expansion," a set of culturally entrenched values stressing the fertility of women, land, and cattle. Brandström (1990) suggested that it is this emphasis on fertility that has led to dramatic population increases, a supposition echoed more generally by biological anthropologists (Bentley et al., 2001). In contrast to the assumption that increased fertility underlies the Sukuma expansion, recent modeling and empirical work suggest that reproductive fitness (at the population and individual levels) is affected more by reductions in child mortality than by increases in fertility. Using a life table modeling exercise, Pennington (1996) illustrated how improvements in child mortality rates can lead to dramatic increases in populations, even with no changes in fertility and declines in life expectancies. She suggested that this may explain the dramatic population increases associated with agriculture, a supposition supported by the finding that child mortality is inversely related to reliance on foraging in a phylogenetically controlled cross-cultural sample (Sellen and Mace, 1999). Looking within a single population, Strassmann and Gillespie (2002) found that, among a cohort of Dogon women, more of the variance in women's lifetime reproductive success is explained by differences in infant mortality than by differences in fertility. Taken together, these models and empirical work suggest that the Sukuma expansion (and, more generally, ethnic expansions) may be best explained not by increases in women's fertility, but rather through reductions in childhood mortality.

Critical to understanding population dynamics is not only identifying whether population growth in any one case is fueled by greater fertility or reductions in mortality, but also developing an understanding of why these parameters differ between certain groups. For instance, biological anthropologists have long been interested in assessing the relationships between mode of subsistence and measures of reproduction and child health. Broad relationships between demographic variables and mode of subsistence have been identified (Hewlett, 1991; Sellen and Mace, 1997; Bentley et al., 1993), but the mechanisms underlying these dynamics are not yet well-understood. This is because many features of a society that are known to influence child health (and therefore child mortality) vary with mode of subsistence, including food availability, settlement patterns, marriage systems, and socioculturally influenced gender and health ideologies. It is therefore important for biological anthropologists to begin to move beyond classification by mode of subsistence and

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investigate in more detail hypothesized determinants of child health (e.g., Sellen and Smay, 2000).

In order to investigate the family-level dynamics of the Sukuma expansion, data on fertility, mortality, and children's health collected from a sample of Sukuma living in Tanzania's Rukwa Valley are compared with similar data from the neighboring horticultural group, the Pimbwe. Both ethnic groups live in the same village, a study design that minimizes possible confounding effects on the outcome variables that may arise from different ecological and geographic settings. Between-group differences in measures of child mortality are first assessed. If reductions in mortality are responsible for population increases, then we would also expect Sukuma children to enjoy greater nutritional status than Pimbwe children because of the clear link between child mortality and children's nutritional status (Pelletier, 1994). After identifying that Sukuma children do indeed experience higher survivorship and nutritional status, four hypotheses that might account for the large differences observed in children's nutritional status are tested. It is hypothesized that the health differences are the consequence of between-group differences in 1) wealth, 2) seasonal household food security, 3) maternal size, or 4) infant feeding practices.

HYPOTHESES AND JUSTIFICATION

Wealth

Sukuma households are wealthier than Pimbwe houses on measures of livestock holdings, acres farmed, and material items owned, and it is plausible that "wealthier is healthier." Households with greater wealth may be associated with reduced mortality and increased nutritional status because they are able to provide children with increased dietary quality and quantity, more hygienic environments, greater access to cash to pay for healthcare, and more alternative caretakers. Specifically, wealthier Sukuma households may be associated with more cattle, and therefore a greater availability of nutrient-rich cow's milk. It is also possible, however, that there is no association between wealth and nutritional outcomes, because poorer households may rely more heavily on nutrient-rich edible wild foods such as fish and greens. Animal-source foods, such as wild game and fish, are known to promote growth (Neumann et al., 2002), and Pimbwe households appear to acquire these foods more frequently than the Sukuma. Indeed, while there are some small differences in composition of the diet of 6–24-month-old children in each group, a 1-month food frequency survey revealed no between-group differences in the frequency of consumption of animal-source foods (Hadley, 2003).

Seasonal household food security

A slightly more specific version of the wealth hypothesis addresses the seasonal nature of food security in the area. Anthropologists (Richards, 1939), nutritionists (Ulijaszek and Strickland, 1993), and anthropological informants working or living in agricultural communities frequently call attention to the potentially devastating preharvest season, a period marked by a host of deleterious outcomes including increased infectious diseases (Tomkins, 1993), increased workloads (Panter-Brick, 1996), reductions in energy intake (Brown et al., 1982) and food availability (Wandel and Holmboe-Ottesen, 1992), deterioration of nutritional status (Adams, 1994; Ferro-Luzzi and Branca, 1993), and increased child mortality (Moore et al., 1997). Because of these patterns, "seasonality" may create and

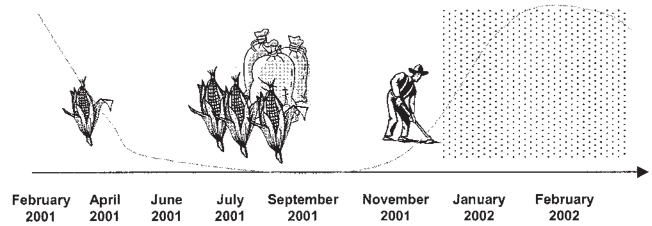

Fig. 1. Schematic of a typical yearly agricultural schedule. Dashed line represents rainfall pattern; shaded area represents preharvest "hunger" season. Maize begins to ripen in March, and primary harvest occurs in July. Clearing and planting occur in November.

subsequently reinforce inequalities in poverty and poor health, not only within but between groups. Seasonal declines in fertility and increases in child mortality would also have large-scale demographic implications.

For most of the year, both the Sukuma and Pimbwe enjoy adequate food supplies, and food availability does not appear to be particularly problematic. During the dry seasons, food stocks were observed to be quite full of maize, children from both groups were routinely observed to leave meals unfinished, and leftovers were commonly consumed as snacks throughout the day, suggesting that food availability during this period of the year is sufficient. In contrast, during the months before the harvest, food security becomes particularly acute, and perhaps biologically important, as many Pimbwe households in the study area report that they have run out of food completely and are living day-to-day, earning food by selling their labor to the Sukuma; this is a common finding among communities with primarily agricultural economies (Fig. 1). Seasonal burdens of limited food availability are also nominated by Pimbwe farmers when asked why the Sukuma seem to thrive in the same environment, and it is a phenomenon noted by anthropologists working with the Sukuma in other parts of Tanzania (Brockington, 2001).

Maternal effects

Many studies report maternal stature as a significant predictor of children's weight and particularly height (Adair and Guilkey, 1997; Ramakrishnan et al., 1999; Schmidt et al., 2002), and point out its importance in the intergenerational transmission of undernutrition (ACC/SCN, 2000). Other studies also linked maternal stature to an increased risk of child mortality, with taller mothers experiencing a significantly lower risk of losing a child. For this reason, it is important to test for any influence of maternal size on child growth. If Sukuma mothers are on average taller than Pimbwe mothers, then their children will be taller and heavier than Pimbwe children. Moreover, maternal weight could also be used as a proxy for maternal size, but because detailed data on the pregnancy status of mothers were not collected, this variable was not used. It is likely that maternal size is associated with children's growth performance because height acts as a proxy for infant birth weight (Martorell et al., 1996), although infant size may also influence maternal feeding decisions (Marquis et al., 1997). It should be recognized, however, that the degree to which these suppositions are true cannot be assessed in this case study. With these limitations in mind, we test whether these small differences can adequately account for the between-group variation.

Infant feeding practices

In environments where the available water supply is potentially a source of contamination and the available complementary foods are poor in dietary quality (Gibson et al., 1998) and may be potential sources of infection, delayed introduction of nonbreastmilk foods reduces the potential for infection via food-borne pathogens (WHO, 1998). Continued breastfeeding also provides the infant with a high-quality, protective food (Lu and Costello, 2000; Victora et al., 1989). There is some evidence that infant feeding practices vary substantially between the Sukuma and Pimbwe, and this could have significant effects on children's early growth performance. For instance, ethnographic observations and focus group reports suggest that, relative to the Pimbwe, Sukuma women were more likely to delay the introduction of solid foods. Unlike Sukuma mothers (see also Varkevisser, 1973), Pimbwe mothers reported that young children and infants needed food to grow and encouraged the early introduction of nonbreastmilk foods. As such, the potential exists for differences in infant feeding practices to underlie the between-group differences in children's nutritional status and infant mortality.

Each of the four hypotheses makes unique predictions about what should be observed in these data. The wealth hypothesis predicts that wealthier children will be healthier, as measured by various anthropometric outcomes. The household food security hypothesis predicts that Pimbwe children should be more heavily affected by the preharvest season, and this should show up as a smaller gain in weight between the dry season and the wet season. Because losses in height are rare, height should generally be unaffected by the preharvest season. The maternal effects hypothesis and the infant-feeding hypothesis predict that large between-group differences should be evident even among the youngest age groups. It is possible to distinguish between these two hypotheses by controlling for mother's height; if maternal effects are responsible for the larger and heavier size of the Sukuma children, then any between-group differences should disappear. After an introduction to the study area, each of these predictions is confronted with data.

STUDY AREA AND PEOPLE

The study area sits in southwest Tanzania's Rukwa Valley (Fig. 2). The area is topographically flat and characterized by dry *miombo* woodland. The Rukwa region is one of the least developed in terms of state infrastructure and is among the poorest in all of Tanzania (World Bank, 2000). Throughout the region, roads are dirt and the vast majority of villages have no electricity or running water. Paradoxically, the Rukwa region is one of the largest producers of corn in the country, and is considered by some to be Tanzania's granary. However, because of the distance to the railway and the largest city (Dar es Salaam), selling of crops brings little profit to local farmers (World Bank, 2000). Within the study area, rainfall begins in November and continues until March or April. At the study site there are a few small stores, a health clinic, and some government offices for the district. A larger health clinic is located approximately 11 km away, and more substantial hospitals are located in the larger towns of Mpanda and Sumbawanga, a 4–6-hr car trip. Malaria is endemic to the area.

Until the 1970s, the Pimbwe, a Bantu-speaking group with the longest known history of residence in the area, were mixed hunter-horticulturalists and goat herders (Willis, 1966). In the 1950s, a large block of land was set aside for a game reserve, which was expanded into Katavi National Park in the 1970s. Because of this expansion, hunting is now illegal and therefore no longer plays a dominant role in Pimbwe culture, although it is still actively practiced. The Pimbwe now live in approximately 10 villages ranging from 240–700 households. Households are constructed of mud bricks and thatched roofs, or rarely, fire-burned bricks and tin roofs. Residence patterns are neolocal: upon marriage, husband and wife move into a new house. Although there are many exceptions, most land is passed on patrilineally. Households are generally quite small, with a modal size of four people, although they can be as large as 13. Agricultural life follows the rains, and farms are typically planted in November, weeded in January and February, and begin to produce maize by late March (Fig. 1). The primary harvest occurs around July, and food stocks are steadily depleted until the following March. Maize is by far the most prominent crop. Peanuts and some variable cash crops are also farmed by a majority of the households. Fields are on average 1–3 acres, although there is reportedly marked variability in productivity across the landscape, and farming is most often done with hoes. Off-farm income-generating activities include the sale of homemade beer, the sale of honey (March), and the harvesting and sale of timber.

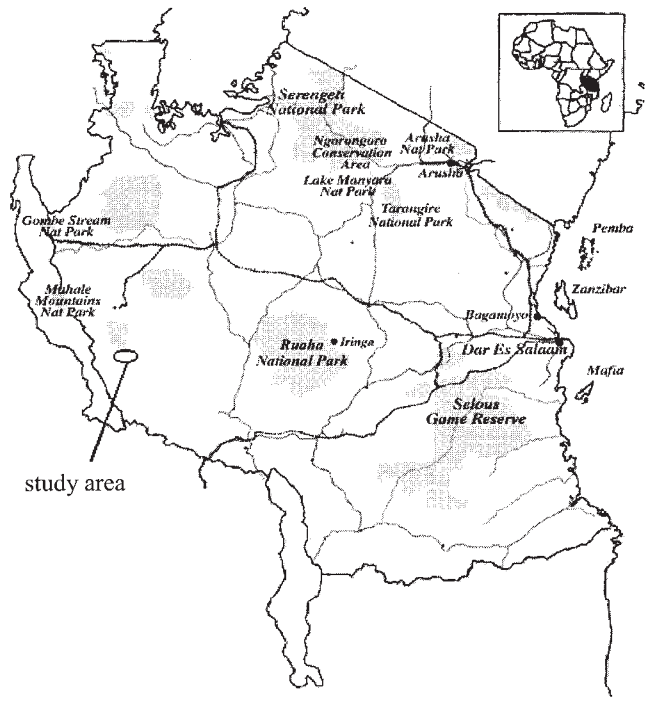

Fig. 2. Map of study area.

The Sukuma are the most populous ethnic group in Tanzania (Brandström, 1990); one of five Tanzanians is now a Sukuma. Like the Pimbwe, they are Bantu-speaking, and they migrated into the study area in the early 1970s, largely as a response to diminishing pasturelands and increasing population sizes in their homeland, the Shinyanga and Tabora regions (Brandström, 1990; Brockington, 2001; Galaty, 1988). The Sukuma are culturally and economically distinct from the Pimbwe and other neighboring groups (Table 1). Colorful and decorative at-

TABLE 1. Comparison of Pimbwe and Sukuma sociocultural features

Trait	Sukuma	Pimbwe
Household size	Mode: 8 (range, 42)	Mode: 4 (range, 13)
Household type	Patrilocal	Neolocal
Marital system	Polygynous	Monogamous
Economy	Cattle, rice farming, maize, peanuts, and potatoes	Hoes, small plots of maize, sunflower, and peanuts
Field size	5+ acres	1–3 acres
Household food security	High	Low

tire, reliance on cattle to plow large plots of land, and their polygynous marital system and large patrilocal settlements distinguish the Sukuma from the neighboring Pimbwe horticulturalists. Unlike the Pimbwe, the Sukuma marital system is marked by a high prevalence of polygyny, and there are as of yet almost no cases of interethnic marriage. Sukuma households are extended patrilocal and patrilineal, and the modal household size is eight people: twice as large as the modal Pimbwe household. The Sukuma practice a mixed economy, herding cattle and cultivating huge amounts of maize and rice, often for commercial resale. Herd sizes range from 1–200, but half of the Sukuma compounds had no livestock holdings at the time of the survey.

METHODS

Demography

Data on women's ethnicity as well as reproductive and marital histories were obtained by retrospective interview from Sukuma women in the villages of Mirumba (data from Monique Borgerhoff Mulder) and Kibaoni, and data on Pimbwe women were from the village of Kibaoni. The collection of reproductive histories was facilitated by the fact that women from both groups were willing to talk about deceased children, and any symptoms leading up to a death. All interviews were conducted in Kiswahili and in every case with a local assistant. Sukuma women in the village of Mirumba were participants in an ongoing demographic project, and individuals from the village of Kibaoni were taking part in a study of children's health and nutritional status. Given the pronounced differences in education between the Sukuma and Pimbwe (Sukuma women are far less likely to have any education), ascertaining women's ages among the Sukuma was often difficult, usually time-consuming, and rarely conclusive. The general strategy was, with the help of a local assistant, to first inquire as to whether the subject knew her age or year of birth. If not, she was asked whether she recalled various historical or local events with known dates. If this failed to produce a seemingly reliable answer, older individuals were called upon to assist in pinpointing her year of birth or approximate age upon arrival in Kibaoni. The lack of digit preference and visual inspection of the fertility and age data suggest that in most cases the final age is probably accurate to 5 years.

Because Sukuma women had difficulty estimating their own ages and experienced considerable trouble estimating the birth dates of children older than approximately 7 years, no effort was made to collect age-specific reproductive histories. Instead, for each woman in the study, information was collected on the total number of live births, the total number of children who were currently living, and the number that died before reaching "about age 5." Similar methods were used for the Pimbwe, although the birth and death dates for most children were known. Statistical analysis was facilitated by placing women into four groups on the basis of the number of children they reported as having died (0, 1, 2, and 3+ children dead).

Anthropometry

Anthropometric data were collected during the early dry season (April 2001) and the wet season (February 2002). The February survey was smaller, with the objectives of weighing more infants and following up a cohort of children weighed in April 2001 (see Household Wealth and Food Security, below). Both surveys followed similar protocols. Height and weight measurements using standard measurement procedures (Gibson, 1990; Shorr, 1986) were made by the author and a trained field assistant (Michael Sungula). Very young children frequently were not measured for length during the initial study because of mothers' reluctance to lay their children on the measuring board. In contrast, most children were measured for length in the 2002 study; in this survey, mothers were shown a picture of a child being measured for length, and this made mothers much more comfortable. Those children who were measured for height were encouraged to stand tall, and the chin-support method was used. Children were minimally clothed and always shoeless. Height measurements were made using a standard height/length board and were taken to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg, using a Seca 890 electronic scale. Children's ages were obtained by looking at birth cards, or by (often lengthy) discussions with mothers and/or other household members.

The children's anthropometric data were converted to z-scores using Epi-Info, the CDC program. The following indices of nutritional status were created: height-for-age z-score (HAZ), weight-for-age z-score (WAZ), and weight-for-height z-score (WHZ). The z-scores represent standardized deviations from the reference median, which is constructed by measuring healthy age- and sex-matched children whose growth has been largely unaffected by undernutrition and frequent bouts of infection. Low values of HAZ are interpreted as evidence of long-term chronic undernutrition. Low values of WAZ are considered indicative of short-term nutritional stress, as are low values of WHZ (Gibson, 1990). Following standard public health protocols used when the relationships between anthropometric measurements and functional impairment and mortality are unknown for a specific population, children presenting with a weight-for-age z-score less than -2 WAZ are considered underweight, children with less than -2 HAZ are considered stunted, and children with a WHZ less than -2 are considered wasted (Gibson, 1990). To control for the clear temporal patterns in the ontogeny of growth faltering that are often associated with weaning (Shrimpton et al., 2001), the data were divided into two groups: infancy and early childhood (0 –<36 months), and middle childhood (36–120 months). This categorization divides children into those who may still be in the process of becoming stunted, and those for whom this process is already completed. After about age 3 years, children's z-scores are unlikely to change very much (Martorell et al., 1994).

Household wealth and food security

In addition to participant-observation and unstructured interviews, in 2002 a survey instrument was administered to a sample of women from 48 Pimbwe households and 32 Sukuma compounds regarding household wealth holdings, which included livestock (cattle, goats), material wealth (ownership of radio, bicycle, drum for water/beer, plow, oxcart), acres of land farmed, and the yield from those acres. Anthropometric measures were also made on the children of the women in these compounds: these children comprised the cohort. The household food security component included items about whether maize stocks ran out prior to the harvest, the date this occurred, and whether the respondent felt that they had enough food during the preharvest wet season. In the event that food was reported as insufficient, respondents were asked what action(s) was taken by the household to alleviate food insecurity. Individuals were also asked whether they had sold any food or assets during the season and for what reason. This latter question was aimed at distinguishing between those households that sold food or assets to purchase household or "luxury" items and those that sold items to augment food stores. Maize stocks were taken as an indicator of household food security because they are the dominant food for both ethnic groups. This is evidenced by the fact that nearly every meal observed was a maize-based dish. Moreover, informants only consider having eaten a meal if it included maize; meals of rice, for instance, are typically seen as snacks.

Statistical procedures

These data were used to test for differences at the population level between the Sukuma and Pimbwe in women's fertility, child mortality, and children's nutritional status. Multiple regression was used to test for differences in fertility between groups while controlling for the mother's age. Multinomial logistic regression was used to test for differences in child mortality between groups while controlling for total births and mother's age (Stokes et al., 1995). Differences in household food security between ethnic groups were assessed using *t*-tests and chi-square tests.

The analytic strategy for the anthropometric data was twofold. First, for the cross-sectional survey, *t*-tests and multivariate models were used to compare the derived nutritional indices between groups. Second, for the cohort data, paired *t*-tests and multivariate models were used to compare changes in children's anthropometric indicators across season of measurement. In all multivariate models, multilevel modeling was used to accommodate an additional source of variability in estimates of nutritional status, which is that many children were measured from the same household. This accounts for the dependencies in the data, a property that would likely lead to biased statistical tests using ordinary least square regression techniques (Littell, 1996).

RESULTS

Group-level differences in fertility and child mortality and children's nutritional status

In addition to the cultural and economic differences, there are differences in child mortality rates, as would be expected if low mortality rates fuel the Sukuma expansion. Initial estimates of child mortality from 133 Pimbwe and 182 Sukuma mothers suggest that Pimbwe children

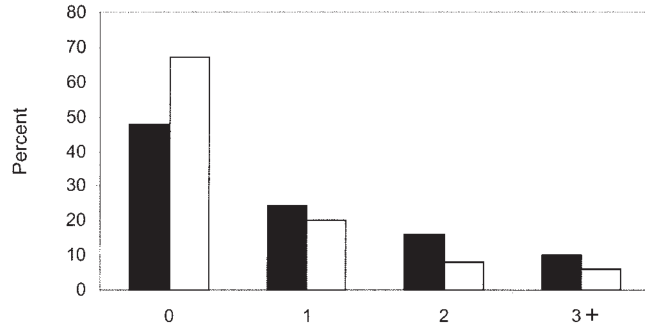

Fig. 3. Between-ethnic group differences in child mortality. In a model controlling for age and parity, Sukuma women experience lower rates of child mortality (N_{Sukuma} = 182, N_{Pimbwe} = 132, P = 0.02). Percent of women reporting 0, 1, 2, and 3+ children deceased before reaching age 5 years. Solid bars, Pimbwe; open bars, Sukuma.

have a significantly higher probability of dying before age 5 than do Sukuma children. A multivariate multinomial regression analysis reveals that even after controlling for the total number of children a woman has given birth to and/or her age (these two are obviously highly correlated), Sukuma women experienced lower child mortality (χ^2 = 5.23, P = 0.02). This is clear in Figure 3, which shows that Pimbwe women experienced greater child mortality. Most noticeable is the sizable difference in the frequency of women who reported no children dying: 60% of Sukuma women reported not having any children die, compared to 40% of Pimbwe women. Even after controlling for any age effects, Sukuma women did not experience more live births than the Pimbwe (Sukuma, 4.6 live births; Pimbwe, 4.5 live births; P = 0.49), but because the difference between the two samples lies in the number of children who died before age 5, Sukuma women reported significantly more children surviving past age 5 (Sukuma, 4.07 children; Pimbwe, 3.66 children; P = 0.03). This suggests that the Sukuma expansion may be the result of reduced mortality, and not increased fertility.

The data to assess whether there are differences in children's nutritional status are a subset of the full anthropometric data set and include only information on dry-season weight and height for children 10 years and younger (n = 474 before exclusions). Within this subsample, children were excluded from the analysis if they had an extreme weight or height-for-age z-score (greater or less than 2 SD from the sample mean for each ethnic group and survey), suggesting that age was estimated incorrectly. This resulted in the exclusion of 34 (~7%) individuals. There were no differences between ethnic groups in the percentage of children excluded for extreme weight and height values (χ^2 = 1.17, P = 0.28). Descriptive statistics and sample sizes after exclusions are shown in Tables 2 and 3.

Sukuma children's scores on every indicator but one were closer to the reference median than were the Pimbwe scores, suggesting that, on average, Sukuma children enjoy better nutritional status than their Pimbwe neighbors. In the infancy and early childhood group, the proportion of Pimbwe children presenting with a WAZ score less than the −2 WAZ cutoff was very high according to the WHO classification and strikingly greater than among Sukuma: 32% of Pimbwe fell below the −2 cutoff, compared to just 11% of Sukuma children (χ^2 = 13.7, P = 0.0002).

TABLE 2. Dry-season (April 2001) anthropometric descriptive statistics for children in infancy and early childhood group (0–36 months)

Group	Age (months)	WAZ	% male
Pimbwe	17.12 ± 9.67	−1.50 ± 1.14	48
N	98	98	
Sukuma	18.61 ± 11.10	−0.62 ± 1.14	47
N	106	106	
t-test *t*	−1.02	−5.48	0.06[1]
P	0.31	<0.0001	0.8[1]

[1] Chi-square test.

Evidence from the middle childhood group also suggests greater nutritional status among the Sukuma (Fig. 4). The prevalence of underweight among the Pimbwe was high according to the WHO classification: 28% of Pimbwe children fell below the −2 WAZ cutoff, while just 6% of Sukuma children did ($\chi^2 = 21.8$, $P < 0.0001$). Prevalence of stunting was also high, with 37% of Pimbwe children presenting with a HAZ score less than −2 SD from the reference median. In contrast, only 9% of Sukuma children had an exceptionally low HAZ score ($\chi^2 = 23.4$, $P < 0.0001$). The prevalence of wasting was low: very few children presented with a WHZ score below the −2 WHZ cutoff (Pimbwe, 4%; Sukuma, 1%), and the difference between groups was not statistically significant. Only the measure of fat from the triceps site was in an unexpected direction, although the difference was not statistically significant.

A possible confounding effect lies in the fact that Sukuma children in the middle childhood group were on average about 6 months younger than the Pimbwe children (Table 3). To control for this, multivariate models were used which controlled for child age (and age squared), and included children's sex and ethnic group as covariates. This did not drastically alter the results (Table 4 and Fig. 5). Sukuma children, as expected, were substantially taller and heavier for their age and sex than were Pimbwe children. Moreover, Sukuma children presented with significantly larger arm circumferences, although this difference was not accounted for by fat thickness, and suggests that Sukuma children have significantly more upper arm muscle than Pimbwe children.

It is noteworthy that the interaction term of child age and ethnic group was not significant for any outcome, suggesting that the difference between these two groups remains relatively constant up to at least 10 years of age. It is possible, however, that this is due to a cohort effect, and those children with low nutritional status suffer higher rates of mortality and therefore do not show up in the sample. This would minimize the difference between the two groups. Also, there was no evidence of sex-biased parental investment, as the interaction effects between ethnic group and sex were not significant for any of the outcome variables, consistent with findings throughout much of sub-Saharan Africa (Cameron, 1991). The magnitude of the between-group difference observed across all anthropometric scores suggests that these differences are real and have considerable biological significance. For example, by 5 years of age, Sukuma children are ~1.5 kg heavier and 5.5 cm taller than Pimbwe children.

WHY DO SUKUMA CHILDREN HAVE GREATER NUTRITIONAL STATUS?

Wealth differences

Sukuma households scored considerably higher on all measures of wealth. Sukuma households reported significantly greater livestock holdings, acres farmed, bags of food produced, and material wealth holdings (Table 5). Compared to the Pimbwe, the Sukuma scored twice as a high on the number of material items owned (2.3 vs. 1.2 items), held 27 more cattle and/or goats (29 vs.1 livestock items), farmed three times as much land (6 vs. 1 acres), and produced approximately 10 more 100-kg bags of food (26 vs. 3 bags).

In spite of these rather large differences in overall wealth, there was no apparent relationship between greater wealth and children's nutritional status. Several multivariate mixed models were fit to data from both the 2001 and the 2002 cross-sectional surveys that separately included terms for material wealth, livestock holdings, and acres. This resulted in a total of 516 measurements on 336 children from the 80 households. In no case did the wealth variables predict anthropometric outcomes. Separate models were initially fit to the infancy and early childhood group as well as the middle childhood group, but the results were similar, so all data were grouped.

In each model, the ethnic group variable remained a statistically significant predictor of children's weight-for-age z-score ($P < 0.05$), but acres ($F = 0.01$, $P = 0.93$), livestock ($F = 0.71$, $P = 0.39$), and material wealth holdings ($F = 0.49$, $P = 0.48$) did not. Similar results were found for height-for-age z-score. To account for the potential influence of collinearity, each model was estimated again to look at the relationship between the wealth variables *within* ethnic groups. These analyses also showed no relationship between wealth holdings and anthropometric outcomes. Lastly, the livestock variable was collapsed into a dichotomous variable (0, none; 1, one or more livestock animals) to assess whether owning any livestock was associated with greater nutritional status. However, even this variable was not associated with children's WAZ ($F_{\text{any cows?}} = 0.84$, $P = 0.36$) or HAZ ($F_{\text{any cows?}} = 0.27$, $P = 0.60$). The large wealth differences apparently do not directly underlie the large differences in children's nutritional status.

Household food insecurity

Data from the survey instrument confirmed informants' statements by showing that Pimbwe households clearly experienced a higher risk of household food insecurity during the critical preharvest season. The sample from 48 Pimbwe households and 32 Sukuma compounds showed that the Pimbwe reportedly ran out of food on average about 4 months earlier than did Sukuma households (*t*-test, $t = -5.10$, $P < 0.0001$). Not surprisingly, the Pimbwe were far more likely to report that their "food ran out early" ($\chi^2 = 22.1$, $P < 0.001$), and that they "did not have enough food" ($\chi^2 = 19.9$, $P < 0.001$). The Sukuma were also far more likely to report selling food in order to purchase common household supplies, again suggesting an abundance of food ($\chi^2 = 13.6$, $P < 0.001$).

Avenues to alleviate or mitigate the stress of seasonal food shortages were also more plentiful for the Sukuma than the Pimbwe. Even in the event that a Sukuma household did run out of food, many had cattle to sell, whereas very few Pimbwe reported any assets of sufficient value so

TABLE 3. Dry season (April 2001) anthropometric descriptive statistics for middle childhood group (3–10 years)

Group	Age (months)	WAZ	HAZ	WHZ	% male
Pimbwe	72.4 ± 24.7	−1.42 ± 0.96	−1.64 ± 1.10	−0.34 ± 0.93	44
N	156	156	138	108	
Sukuma	66.1 ± 21.3	−0.47 ± 0.97	−0.51 ± 1.16	0.02 ± 0.85	44
N	114	114	101	75	
t-test *t*	2.18	−7.82	−7.60	−2.67	0.006[1]
P	0.03	<0.0001	<0.0001	0.008	0.93[1]

[1]Chi-square test.

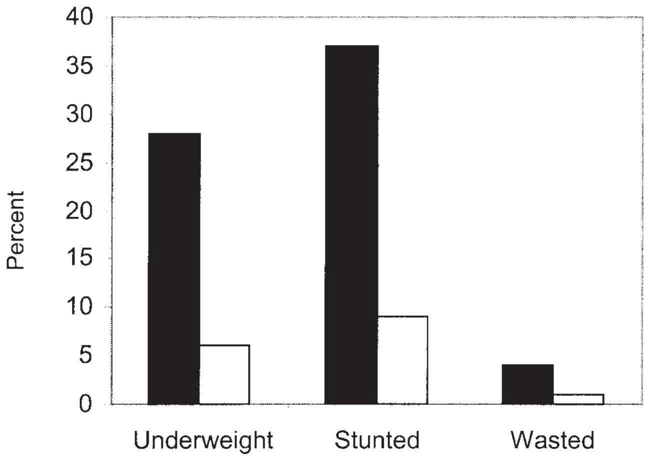

Fig. 4. Between-ethnic group differences in prevalence of underweight, stunting, and wasting among children 3–10 years old. Sukuma children experience significantly lower prevalence of underweight ($P < 0.001$), stunting ($P < 0.001$), and wasting ($P < 0.001$). Solid bars, Pimbwe; open bars, Sukuma. Sample sizes: underweight, Pimbwe, 138; Sukuma, 114; stunting, Pimbwe, 138; Sukuma, 101; wasting, Pimbwe, 108; Sukuma, 75.

as to adequately buffer the seasonal food shortages. No Pimbwe in this sample reported having any cattle, whereas 53% of Sukuma households owned some cattle, and this ranged from 1–200. Sixty percent of the Pimbwe reported not owning any goats, but only 21% of Sukuma households did not have any goats. Sukuma households owned as many as 40, but the Pimbwe house with the most goats had only seven.

If seasonal household food insecurity is responsible for the smaller achieved size of the horticultural population, then this should manifest itself in a greater decline of nutritional indicators for Pimbwe than for Sukuma children in the preharvest wet season period. To assess whether Pimbwe children gained less weight and height in the period between surveys, a series of paired *t*-tests was performed, comparing the change in dry season and wet season WAZ and HAZ values. In total, repeated measures of weight were available for 117 (Pimbwe = 57) children who were less than 3 years old in April 2001. The mean age of children in this cohort (47% boys) was 17.2 months. For children 3–10 years old, 127 (Pimbwe = 63) completed weight series were available, and 113 (58 Pimbwe) of these children had a completed height series. In this group, the average age of Pimbwe children was about 7 months older than the average age for the Sukuma (*t*-test, $P = 0.09$), and overall a greater proportion of girls was measured (63% girls, binomial $P = 0.002$).

Unexpectedly, in the infancy and early-childhood group, only Sukuma children showed statistically significant declines in their WAZ scores between seasons of measurement. For Sukuma children, mean WAZ declined from −0.69 (SD, 1.29) to −1.13 WAZ (SD, 1.50; paired *t*-test, $P = 0.003$). In contrast, Pimbwe children in this age group showed small but statistically insignificant declines, with WAZ declining from −1.37 (SD, 1.25) to −1.60 WAZ (SD, 1.32; paired *t*-test, $P = 0.13$). The magnitude of decline was so great for the Sukuma that the large between-group difference seen in the dry season was only marginally significant in the wet season ($P_{\text{dry season}} = 0.005$, $P_{\text{wet season}} = 0.06$). For children in both ethnic groups, the magnitude of change in WAZ was unrelated to any measure of wealth (Livestock F = 1.31, $P = 0.26$; Acres F = 0.18, $P = 0.67$; Wealth F = 1.36, $P = 0.26$), nor was the date at which foods stocks were depleted associated with children's change in WAZ (F = 0.01, $P = 0.91$).

Children in the middle-childhood group from both ethnic groups showed marked and statistically significant declines in their relative weight scores. Pimbwe children went from −1.27 WAZ to −1.48 WAZ (paired *t*-test, $P = 0.0002$), and Sukuma from −0.60 WAZ to −0.77 (paired *t*-test, $P = 0.002$). The magnitude of this decline was similar for each group (*t*-test, $P = 0.55$), but Sukuma children were still much heavier for their age than were Pimbwe children in both the dry season (*t*-test, $P = 0.0005$) and wet season (*t*-test, $P = 0.0002$) samples. In contrast to the relative weight loss, children's height-for-age z-scores showed no decline during the wet season (Pimbwe paired *t*-test, $P = 0.85$; Sukuma = 0.54), suggesting that loss in weight represents short-term nutritional stress, and is not merely an effect of aging.

Among the middle childhood group, children's change in WAZ scores across seasons was also not associated with livestock ownership (F = 2.06, $P = 0.16$), material wealth holdings (F = 0.61, $P = 0.44$), and acres farmed in the previous year (F = 0.41, $P = 0.53$); nor was it associated with the date at which maize stocks were depleted (F = 0.23, $P = 0.63$), or whether the house had already run out of food in February, i.e., the time of the anthropometric survey (F = 1.44, $P = 0.24$).

Taken together, these results suggest that household food security during the preharvest season is not directly related to the large differences seen between groups in children's growth.

Maternal effects and infant feeding

The inability of the wealth or household food security variables to account for a significant portion of the variation, coupled with the observation that the between-group variation in children's achieved weights is evident even at the youngest age groups (Table 2), suggests that factors other than wealth and household food security are at play. Unfortunately, very few young children were measured for height/length in the 2001 survey, making it difficult to

TABLE 4. Results of multiple regression predicting children's (3–10-year) WAZ, HAZ, and WHZ

	WAZ		HAZ		WHZ	
Effect	β (SE)	*P*	β (SE)	*P*	β (SE)	*P*
Intercept	0.96 (0.62)		−0.23 (0.75)		2.84 (0.84)	
Ethnic group (Pimbwe)	−0.87 (0.15)	<0.0001	−1.08 (0.19)	<0.0001	−0.23 (0.16)	0.15
Sex (F)	−0.04 (0.12)	0.73	0.10 (0.13)	0.44	−0.13 (0.12)	0.29
Age (months)	−0.04 (0.02)	0.03	−0.02 (0.02)	0.45	−0.07 (0.02)	0.005
Age squared	0.0002 (0.0001)	0.05	0.0001 (0.0001)	0.35	0.0004 (0.0002)	0.02
N	270		239		183	

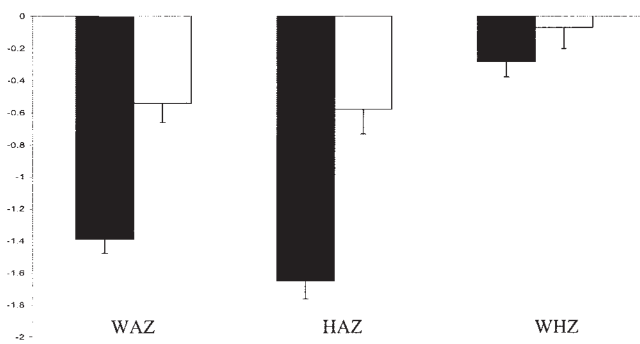

Fig. 5. Sukuma and Pimbwe children's (ages 3—10 years) model adjusted (for age and sex) weight-for-age z-score (WAZ), height-for-age z-score (HAZ), and weight for height z-score (WHZ). After controlling for age, Sukuma children are significantly taller ($P < 0.001$) and heavier ($P < 0.001$) than Pimbwe. Bars show 1 standard error. Sample sizes are: WAZ, Pimbwe, 138; Sukuma, 114; HAZ, Pimbwe, 138; Sukuma, 101; WHZ, Pimbwe, 108; Sukuma, 75.

fully assess the age at which between-group differences emerge. Fortunately, in 2002, 60 children under age 3 years entered the study, and most of them were measured for both length and weight. Those young children who had been weighed in 2001 were also measured for height in 2002. Together these samples provide the opportunity to further investigate the time at which the differences between these groups manifest. From these data, a small number of children less than 12 months old were extracted (22 Sukuma children, of which 19 were measured for length; 27 Pimbwe children, 22 measured for length) to test for between-group differences in nutritional status. Even at this young age, the differences in HAZ and WAZ were evident and had considerable magnitude. The Pimbwe children's HAZ was −1.05 (SE, 0.20), whereas the Sukuma children's was −0.32 HAZ (SE, 0.17; F = 8.10, $P = 0.007$). WAZ values were also different: the Pimbwe children's mean WAZ was −1.19 WAZ (SE, 0.23), while the Sukuma children's was only −0.53 WAZ (SE, 0.20; F = 4.64, $P = 0.04$).

The observation that the between-group weight and height differences are set at an early age directly implicates maternal effects and/or differences in young child feeding practices. Using wet-season 2002 data for all children less than 2 years old for whom maternal height was known (maternal height $N_{Pimbwe} = 28$, $N_{Sukuma} = 41$), a maternal height (in cm) terms was added to the models to test whether differences in maternal height explained between-group differences in WAZ and HAZ. This revealed statistically significant effects of ethnic group, but only marginally or nonsignificant effects of maternal height (WAZ $F_{ethnic} = 7.68$, $P = 0.007$, $F_{momcm} = 3.44$, $P = 0.07$; HAZ $F_{ethnic} = 4.10$, $P = 0.04$, $F_{momcm} = 1.07$, $P = 0.31$), suggesting that infant feeding practices may be important in explaining group-level differences, although given the small sample sizes, the maternal effects hypothesis cannot be rejected.

Infant feeding patterns were investigated by looking at the age that *uji* (a watery maize-based gruel that is the first solid food introduced to children) was reportedly introduced to children. Data on recalled age of introduction of *uji* were available for 115 children ($N_{Pimbwe} = 56$, $N_{Sukuma} = 59$; for evidence that mothers are able to recall these events with considerable accuracy, see Gray, 1995, 1996; Sellen, 1998). Compared to Pimbwe mothers, Sukuma women delayed the introduction of *uji*. For the Sukuma, the median age at introduction of *uji* was 4 months (95% CI, 3, 5 months). For the Pimbwe, median age at introduction of *uji* was 2 months (95% CI, 1, 3 months; $P \leq <0.0001$). To further test whether there were differences in infant feeding patterns and whether these played a role in the growth differences, data from children less than 6 months of age and whose mothers had participated in the survey on infant feeding practices were analyzed.

Unfortunately, anthropometric and feeding data were only available for 28 children under 6 months of age. However, the results from this small sample are consistent with the hypothesis that different feeding patterns underlie the between-group differences. Sukuma children were significantly less likely to be consuming maize-based foods (*uji*) than were Pimbwe children ($\chi^2 = 5.1$, $P = 0.02$), and children not yet consuming *uji* were heavier (P = 0.04) and slightly taller for their age ($P = 0.06$). The small sample makes multiple regression unreliable to assess the independent effects of ethnic group and feeding behavior, but the data are certainly consistent with the hypothesis that differences in infant feeding practices during this period of rapid child growth underlie the differences in nutritional status observed in these two groups.

DISCUSSION

As expected, the Sukuma experience lower levels of child mortality but levels of fertility that are comparable to their horticultural neighbors. There are also large differences in the nutritional status of children from these two groups, as expected on the basis of theory and ethnographic observations. Also, there was evidence of tremendous differences in household food security at the population level, but contrary to expectation, this does not appear to be the mechanism that affects children's growth velocity or achieved weight across the preharvest wet season. Most children, irrespective of ethnic group, presented with lower relative weight during the preharvest wet season, suggesting that increased labor demands or, more likely, increased infectious disease may be more responsible for the deterioration in nutritional status than issues of food availability. Growth in the period between the two anthropometric surveys was not related to various mea-

TABLE 5. Measures of household wealth by ethnic group (N_{Pimbwe} = 48, N_{Sukuma} = 32)

Group	Livestock[1]	Items owned[2]	Acres farmed[3]	Food produced[4]
Pimbwe	1.3 ± 1.9 (range, 7)	1.2 ± 1.2 (range, 4)	2.1 ± 1.4 (range, 6)	7.3 ± 7.2 (range, 30)
Sukuma	29.1 ± 56.6 (range, 240)	2.3 ± 2 (range, 8)	6.1 ± 4 (range, 16)	26.3 ± 24.6 (range, 105)

[1] Sum of total goats and cattle reported by household.
[2] Sum of radios, bicycles, barrel drums, and oxcarts owned.
[3] Reported acreage farmed.
[4] Reported number of 100-kg bags of food produced.

sures of wealth, a factor that is probably not important in explaining the large between-group difference in achieved size. The limited importance of wealth is also suggested by the observation that differences in children's WAZ and HAZ are evident in even the infancy and early-childhood group. This result, and the failure of an age and ethnic group interaction term to achieve statistical significance, further support the hypothesis that young child feeding practices underlie the large differences in health outcomes observed in these two ethnic groups.

Why Sukuma and Pimbwe mothers differ in their child feeding practices is not yet clear, but the results suggest at least two hypotheses that should be explored in future studies. First, it is likely that Sukuma and Pimbwe mothers face different time constraints, and this impacts their ability to feed and care for their children. For instance, Sukuma households are typically larger than are Pimbwe households, and therefore offer a greater supply of alternative workers to take over women's tasks during pregnancy or when caring for very young children. In contrast, Pimbwe women may have fewer individuals able to tend fields or do chores, and therefore must do these tasks themselves. Early introduction of foods would allow mothers to leave young children behind while they go about their daily chores. The Sukuma also live closer to their fields, which may allow women to return home frequently to nurse and feed their young children. Future studies should employ time allocation data to test whether and why Sukuma mothers are able to provide higher levels of care for their children. A second hypothesis is that the complementary foods available to Sukuma children have greater micronutrient and energy density. The primary food for young children is a thin maize-based gruel (*uji*), whose energy density is related to the amount of water used in preparation. Slightly different preparations could substantially alter the energy density of this meal, and this could have large affects on intake when coupled with increased feeding frequency. Recipe trials could be performed to assess the micro- and macronutrient composition of common complementary foods.

There is also the possibility that some of the between-group differences in health stem from different maternal attitudes toward feeding during bouts of illness. The degree to which infection-induced anorexia influences children's dietary intake and subsequent growth is contingent upon the caregiver's attitude toward feeding during bouts of illness (Dettwlyer, 1989). Thus, the interaction of infection and caregiver practices may be a potent explanatory variable for uncovering the causes of within- and between-group differences in children's growth and health. Evidence against this hypothesis comes from the finding that the majority of Pimbwe mothers report encouraging their children to feed during illness (Hadley, 2002). Future studies should, however, explore this possibility.

It is also interesting that reductions in household food security were not associated with greater declines in children's nutritional status in either ethnic group. Similar results were found by Shell-Duncan (1995) in her study of seasonal changes in nutritional status and morbidity among the Turkana, who practice only very limited agriculture. In that longitudinal study of a small sample of children, measures of food availability were not related to fluctuations in children's nutritional status or incidence of morbidity. However, immunological measures revealed consistently high signals of infection, suggesting the hypothesis that among the Turkana, poor growth reflects high levels of infection, and not food insecurity. The same pattern emerges from a longitudinal study of children's growth in Bangladesh. Brown et al. (1982) showed that seasonal fluctuations in children's nutritional status corresponded to seasonal patterns of rainfall, flooding, and food availability. Most interesting, however, was that nutritional status deteriorated seasonally even among children who were obtaining most of their food energy from breastmilk, and who would therefore not be expected to be directly affected by reduced food availability. These observations suggest that food security in and of itself may not be solely responsible for seasonal declines in nutritional status, and draw attention to the potentially important role of the increased incidence and prevalence of infectious disease.

There is also evidence from the study area that the prevalence of infectious diseases is higher in the wet season than the dry season, which may be responsible for the reductions in relative weights observed in both groups. Data to assess whether or not the incidence and prevalence of morbidity were elevated in the wet season relative to the dry season were not available for the Sukuma, but were available for a sample of the Pimbwe (Hadley, 2003). During the dry-season sampling period, a 1-week recall of illness showed that 13% of 112 children were reported as suffering from some type of ailment. The prevalence of disease among children was more than twice as high during a 1-week recall during the wet season: 27.2% of 117 children were reported as ill. When the data were disaggregated by illness type, the difference in prevalence between the two seasons was due primarily to increases in "colds" (2%, dry season; 8%, wet season) and diarrhea (6%, dry season; 16%, wet season), both of which are diseases mothers associate with reduced appetites in their children. Children were also ill for slightly longer periods of time during the wet season. The median duration of all illnesses during the dry season was 3 days, whereas it was 7 days during the wet season. Comparable data from Sukuma children are needed to assess the relative influence of morbidity on growth performance in each of these groups.

CONCLUSIONS

In this study, Sukuma women were compared with a group of Pimbwe horticulturalists to show that child mortality was statistically significantly lower among Sukuma women, but levels of fertility were comparable. A second line of inquiry showed that, as predicted, Sukuma children showed signs of greater nutritional status than their horticultural neighbors. Together, these results suggest that reduced child mortality may be fueling the Sukuma expansion. There was little support for the hypothesis that wealth differences or seasonal peaks in food insecurity accounted for this marked difference in nutritional status. In spite of large differences in food security at the population level, the stress of the preharvest season appeared to affect both groups similarly and was not responsible for the reduced size of Pimbwe children. A limited amount of data, however, can be interpreted as suggesting that an increased prevalence of disease may partly underlie the deterioration in nutritional status observed in both ethnic groups during the period between the two anthropometric surveys.

The observation that differences between these two groups were set quite early suggested that the greater health and lower child mortality among the Sukuma are plausibly caused by variation in early infant feeding patterns and, most notably, a delayed introduction of adult foods into the child's diet, a supposition supported by quantitative and qualitative data. This is further supported by the failure of any measure of wealth to predict children's anthropometric outcomes, and is consistent with cross-cultural findings that the age of introduction of solid foods increased with dependence on domestic animals (Sellen and Smay, 2001). Early introduction of complementary foods has been repeatedly shown to adversely affect health and child growth (Goto et al., 2002; WHO, 1998), and it is now generally believed that unsatisfactory child growth is the result of inadequate child-feeding strategies (Semba and Bloem, 2001). While no firm conclusions can be drawn without more precise data on feeding practices, it is tentatively concluded that the large between-group differences in nutritional status and mortality are causally linked to the early childhood environment, and not directly to differences in overall wealth or household food insecurity between these groups. More broadly, these results suggest that future studies of demographic expansions should focus on understanding how social features influence infant and child feeding, as these two areas are fundamental to understanding child mortality.

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