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Household Food Security Is Inversely Associated with Undernutrition among Adolescents from Kilosa, Tanzania[1,2]

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Abstract

Household food insecurity contributes to poor nutritional health, with negative consequences on growth and development during childhood. Although early childhood nutrition needs have received much attention, another important nutritional phase is adolescence. In a sample of 670 adolescents from Kilosa District, Tanzania, this study used 3 approaches to better understand the relationship between food insecurity and undernutrition. First, this study examined the associations between 3 commonly used measures of household food security and undernutrition among 670 adolescents from Kilosa District, Tanzania. The measures of household food security, energy adequacy per adult equivalent, dietary diversity score, and coping strategies index, were strongly correlated with each other and household assets ($P < 0.05$). Second, this study measured the nutritional status of adolescents in this district, finding a high prevalence of undernutrition (21% with BMI-for-age <5th percentile of the National Center for Health Statistics/WHO reference). Third, this study measured the association between the log odds of undernutrition (as the dependent variable) and each of the 3 measures of household food security. In separate models, household energy adequacy per adult equivalent and household dietary diversity score were inversely associated with undernutrition after adjusting for gender, age, puberty, and the interaction between age and puberty. By contrast, a greater use of coping strategies was not associated with undernutrition. Strategies focused on increasing household energy intake and improving dietary diversity among the most vulnerable households could improve the nutritional health of adolescents. J. Nutr. 142: 1741–1747, 2012.

Introduction

Food security, broadly defined, exists "when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (1). Sub-Saharan Africa has made the slowest progress toward reducing hunger compared with all other regions in the world (2) and food security remains one of its most persistent challenges to economic growth (3). Approximately 30% of the population of mainland Tanzania was unable to meet their basic food needs due to extreme poverty (4).

Studies conducted within the past 15 y found a high prevalence of undernutrition (15–58%) among adolescents in sub-Saharan Africa (5–8). These findings, along with projections that approximately one-third of Africa's total population will be between 10–24 y of age by 2025 (9), raise concerns for national health and economic development. Evidence suggests that children living in food-insecure households experience poorer nutritional, health, and psychosocial outcomes (10–16).

Undernutrition is a major public health concern for adolescents (10–19 y) in developing countries (17), with negative implications for growth (18), brain development (19), birth outcomes (17,20,21), and long-term health (22). Poor nutritional status lowers productive capacity (23), compromises resistance to disease (24), and adversely affects cognitive development (25). Children entering adolescence chronically undernourished can experience delayed pubertal development and prolonged growth (17). Undernutrition during adolescence may compromise health status across generations, because undernourished young women are most likely to have low-birth weight infants (17,21), who in turn are likely to experience poor health and have fewer chances for survival (21,24).

The theoretical framework for this study holds that insufficient access to food at the household level can compromise food availability and diet quality for individual household members (13,16,21). Adolescents in rural areas of developing countries often assume adult farming responsibilities, leading to higher levels of energy expenditure. This coincides with greater energy and micronutrient requirements due to sexual maturation and linear growth (17). The relationship between food insecurity and undernutrition is synergistic. In a food-insecure environment, nutrient losses due to energy expenditure, menstruation, and

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disease can increase risk for undernutrition. In addition, poor nutrition at any age can influence resistance to illness and disease outcomes (21,24,25), which in turn may lead to negative consequences on long-term health, productivity, and household food security. We expect that household food security has an effect on food availability and dietary diversity, consequently affecting the nutritional status of adolescents in those households. This study examined the association between household food security and undernutrition in a cross-section of adolescents living in rural Tanzania.

Methods

Study population. Conducted under the auspices of UNICEF/Tanzania in 2003–2004, this cross-sectional study employed a 2-stage sampling plan. In the first stage, 30 villages were selected for inclusion in the study using probability-proportional-to-size cluster sampling without replacement. In the second stage, a simple random sample of 30 adolescents was drawn for each village from a master list of individuals born between 1984 and 1994 in that village. Master lists were generated from village registries, which document the names and ages of all household members. This sampling plan produced a representative sample of villages and adolescents in Kilosa District (n = 900). Survey research was completed in 28 villages (n = 840); the remaining 2 villages were inaccessible due to weather conditions. The survey response rate was 94.2% (n = 791).

For this analysis, we excluded adolescents who did not meet the age criterion for inclusion (i.e., 10–19 y), with missing age (n = 92), and/or were not listed as household members in household surveys (n = 8). Adolescent girls who were either pregnant (n = 8) and/or ≤4 mo postpartum (n = 12) were excluded from the analytical sample, because BMI is not a reliable measure of nutritional status during these life stages (26). Married adolescents (n = 35) were also excluded from analyses, because their household composition and socioeconomic status significantly differed from never-married peers. The analytical sample was composed of never-married adolescents who at the time of the study were either nulliparous, not pregnant, or ≥4 mo postpartum (n = 670). A total of 128 (19%) of these adolescents had at least one missing value; 2.5% were missing data on nutritional status, and 3% were missing data on puberty. At the household level, 85 households had missing data on household energy adequacy, 2 on household dietary diversity, and 44 on the household's coping strategies index (CSI)[6].

Data collection took place from December 2003 to March 2004 during the hot dry season, a period of peak food shortage, following standard procedures for food security assessments in developing countries (P. Webb, Tufts University, personal communication). We conducted focus groups with 32 adults in 4 selected villages to understand their perspectives on food security and coping strategies utilized during food shortage and to rank coping strategies by frequency of use and severity (27). Focus group data informed survey item development.

Household and adolescent surveys were administered in Swahili by trained interviewers at the adolescent's residence. Interviewers attended 1 wk of training on general interviewing techniques, ethics, obtaining consent, reading questions in entirety, recording responses accurately, conducting 24-h dietary recalls, and reporting concerns to field supervisors. Survey instruments were pretested in a nonparticipating village. Heads of households provided information on demographic, health, and socioeconomic characteristics of their households. Dietary recalls at the household level were completed with the principal food preparer(s). Adolescents, interviewed separately and in private by interviewers of the same gender, provided information on their own demographic, physiological, health, behavioral, and dietary characteristics. Anthropometric assessments of adolescents were conducted at a central location in each village. Consents and assents were obtained from heads of households and adolescents, respectively, at their initial interview contact.

This study was approved by the Institutional Review Board at Tufts University and the Tanzania Commission for Science and Technology. Permission to conduct field research was also granted by the Morogoro Regional Administration and Kilosa District Council.

Household food security measures. At the time of this study, indicators such as household energy adequacy per adult equivalent (EnergyAdq), the household dietary diversity score (HDDS), and the CSI as well as various modifications of the U.S. Household Food Security Survey Measure (HFSSM) had been validated in developing countries (27–29). Research contributing to the development of the household food insecurity access scale (HFIAS), an internationally standardized benchmark indicator of household food security, was also underway (30–34). Based on recommendations for using "a convergence of evidence" from multiple indicators in the absence of a gold standard measure of food security (30), we collected data on 3 indicators measuring different dimensions of household food security.

The EnergyAdq measures food access and consumption and was derived from one 24-h dietary recall per household (35). Individuals with primary responsibility for preparing meals reported on recipes prepared, type and quantity of ingredients used, and amounts of food consumed by household members and guests. Data were coded using the Tanzania Food Composition Tables (36) and analyzed by Harvard University School of Public Health. Household energy adequacy was assessed by energy consumption as a percentage (1 unit change = 10 percentage point change in household energy adequacy) of household energy requirements per adult equivalent (35). The obtained range for EnergyAdq was 2–195%.

The HDDS measures dietary quality (28,37). It counts the number of different food groups represented in the household's diet. Household dietary recall data were coded according to a set of 12 food groups (37), including cereals, fish and seafood, roots and tubers, pulses/legumes/nuts, vegetables, milk and milk products, fruits, oil/fats, meat/poultry/offal, sugar/honey, eggs, and miscellaneous. The possible range for HDDS was 0–12 and the obtained range was 1–9.

The CSI assesses the frequency and severity of coping strategies used by households during periods of food shortage (27). The development of a CSI is based on qualitative data assessing strategies employed by households to mitigate food insecurity (27). We conducted focus group discussions in 4 villages in Kilosa District to gather data on locally and culturally appropriate coping strategies used during food shortage. Focus group participants then ranked strategies by frequency of use and order of severity. Greater weights were assigned to more severe strategies (27). Households reported on 16 items in the CSI survey module used in the past 30 d. Strategies included consumption of less preferred foods, skipping or reducing meals, reducing portion sizes, borrowing food, consumption of wild foods or immature crops, and sending household members/children elsewhere to eat. Responses to these items are weighted and summed to create an index where higher scores are indicative of greater food insecurity. The obtained range for CSI was 0–143. We observed a Poisson distribution for CSI. After examining plots of various data transformations, we applied a square root transformation to CSI to normalize right skewness and improve model fit.

Undernutrition. We collected anthropometric data on adolescents, the primary unit of analysis for this study. Two measurements of height and weight were collected for every adolescent and the means were used to calculate BMI. Height was measured to the nearest 0.1 cm using 2-m height boards. Weight was measured to the nearest 100 g using calibrated electronic scales (SECA). Undernutrition was defined as BMI (kg/m^2)-for-age and -sex <the 5th percentile of the National Center for Health Statistics (NCHS)/WHO reference population (38,39).

Covariates. A preliminary analysis investigated a wide variety of other factors that influence health and nutritional status, identified from bivariate analysis and previous research. To improve the efficiency of the

[6] Abbreviations used: CSI, coping strategies index; EnergyAdq, household energy adequacy per adult equivalent; HDDS, household dietary diversity score; HFIAS, household food insecurity assessment scale; HFSSM, U.S. household food security survey measure; MET, metabolic equivalent of task; NCHS, National Center for Health Statistics.

models in predicting the dependent variable, undernutrition, the final multivariate models included a smaller set of explanatory variables. The initial list of explanatory variables is described here: *1*) age was centered at the mean to ensure meaningful interpretation of regression parameters, because the intercept value is interpreted at 0 y, whereas the age range for this sample was 10–19 y; 2) pubertal attainment was based on self-reported age of menarche for each adolescent girl and self-reported age of first voice change for each adolescent boy. Menarche and voice change, quantifiable biomarkers of pubertal growth and indicative of a late stage of sexual maturation (40,41), provide a rough estimate of pubertal attainment. Tanner's Sexual Maturation Scale is the standard clinical assessment of puberty but is difficult to implement in population-based studies (42). We created a dichotomous variable for puberty to estimate attainment of pubertal landmarks across gender. Respondents who reported reaching menarche or experiencing voice change were categorized as having attained puberty (coded "1"), whereas those who did not report reaching these landmarks of sexual maturation were prepubertal (coded "0"). *3*) The religious affiliation of adolescents was reported by the household respondent. Of those with data on religious affiliation, 99% were either Christian or Muslim (n = 602) and 1% had no religious affiliation (n = 6). The latter were set to missing for descriptive purposes. *4*) An adolescent was categorized as an orphan if s/he reported that either one or both of his or her parents were deceased. In all cases, the year of the parent(s) death was recorded and verified with the household respondent. *5*) Adolescents that reported current school attendance were considered enrolled (coded "1"); those unenrolled were coded "0"; *6*) physical activity status was assessed in metabolic equivalent of task (MET) min/wk using the short version of the International Physical Activity Questionnaire (43). Participants who reported expending ≥3000 MET min/wk were considered to have high levels of physical activity (coded "1"), whereas those who reported expending <3000 MET min/wk were considered to have low/moderate levels of physical activity (coded "0") (43). *7*) Morbidity was assessed by the number of self-reported symptoms of illness/morbidity experienced in the last 30 d or last 12 mo, depending on the specific illness, disease, or symptom experienced (44). Symptoms included episodes of malaria, tuberculosis, acute respiratory infection, acute diarrhea, ear discharge, oral candidiasis, parotid swelling, and enlarged lymph nodes in ≥2 of the following sites: neck, groin, and axillae (44). Morbidity was entered as a continuous variable in regression models. Adolescents' self-reports and their caregivers' reports of the adolescent's morbidity were highly correlated, providing validity of this assessment tool during adolescence. *8*) Socioeconomic status was measured using household assets as an indicator of wealth and household expenditure as proxy of income. Data data on the type and number of assets was collected from all households in this sample. Assets were priced according to their cost in 2004 and converted into their monetary value (10,000 Tanzania shillings were equivalent to $9.21 US in 2004). The total sum of all assets was calculated for each household. In this paper, household assets were expressed as terciles for descriptive and regression analyses. Total household expenditures for the past 30 d were reported by heads of households. Expenditures were expressed in units of 10,000 Tanzanian shillings ($9.21 US).

Statistical analysis. Data were analyzed using SPSS version 19.0. Differences were considered significant at $P < 0.05$. For prevalence estimates, means, and medians, missing data were excluded from the analyses. The values presented are means ± SD. The Pearson correlation analysis was used to test the correlations between undernutrition, socioeconomic status, and the 3 indicators of household food security considered in this study. Pearson chi-square tests were used to examine associations between undernutrition and various sociodemographic as well as physiological characteristics. Independent samples t tests were used to compare the mean values of all 3 measures of household food security between well-nourished and undernourished adolescents. Main effect logistic regression models examined the linear and quadratic associations of household energy adequacy and household dietary diversity with undernutrition after adjusting for age, puberty, gender, school enrollment, physical activity, morbidity, socioeconomic status, and the interaction term age × puberty. The relationship between CSI and undernutrition was tested using logistic regression after adjusting for the covariates listed above. Reduced-form models were constructed to improve the efficiency of the model in predicting the dependent variable, undernutrition. The reduced-form models considered each measure of food security separately after adjusting for other significant covariates of undernutrition represented in the full model: age, puberty, gender, and the interaction term age × puberty. A comparison of food security coefficients is presented in the results.

Results

Household food security measures. EnergyAdq and HDDS were positively and strongly correlated with each other ($P <$ 0.05) and negatively correlated with CSI ($P < 0.05$) (**Table 1**). The latter correlation indicated that households employed more coping strategies, and with greater frequency, as their diet quantity (EnergyAdq) and quality (HDDS) declined. All 3 food security indicators were correlated with household assets ($P <$ 0.05). The negative correlations between undernutrition and the variables EnergyAdeq and HDDS ($P < 0.05$) indicated that the risk for undernutrition among adolescents was lower when their households experienced greater energy adequacy and dietary diversity.

Each of the 3 dimensions of food security considered in this study appeared to be normally distributed, with marginal differences in mean and median values (**Table 2**). More than one-half of the households in this analytical sample met at least 80% of their energy requirements per adult equivalent, and the mean number of food groups consumed by households was 4 ± 1. Household scores for CSI ranged from 0 to 143, with a calculated mean score of 44 ± 34.1. Focus group discussions in participating villages revealed a range of coping strategies. In some villages, adults reduced their food consumption so that children were buffered from deprivation. In other villages,

TABLE 1 Correlations between undernutrition, household food security status, and socioeconomic measures among adolescents in Tanzania (n = 670)[1]

	Undernutrition	EnergyAdq (%)	HDDS	CSI	Household assets	Household expenditures
Undernutrition	1					
EnergyAdq (1 unit = 10 percentage points)	−0.09*	1				
HDDS	−0.08*	0.41*	1			
CSI	0.002	−0.21*	−0.26*	1		
Household assets	−0.09*	0.23*	0.27*	−0.35*	1	
Household expenditures	0.05	0.11*	0.08*	−0.07	0.15*	1

[1] Tests of significance are based on Pearson correlation (2-tailed), *$P < 0.05$. CSI, coping strategies index; EnergyAdq, household energy adequacy per adult equivalent; HDDS, household dietary diversity score.

TABLE 2 Mean, SD, and median values of 3 measures of household food security among adolescents in Tanzania[1]

	n	Mean ± SD	Median
EnergyAdeq (1 unit = 10 percentage points)	552	85.8 ± 36.1	83.5
HDDS			
Food groups consumed at the household level, *n*	635	4 ± 1.4	4
CSI			
Score	593	44 ± 34.1	39

[1] CSI, coping strategies index; EnergyAdq, household energy adequacy per adult equivalent; HDDS, household dietary diversity score.

intrahousehold food distribution favored working members of the households while other household members cut back their food intake. The mean number of coping strategies employed by households was 5 ± 3, with a range of 0–14.

Prevalence of undernutrition. The prevalence of undernutrition (BMI-for-age <5th percentile of NCHS/WHO reference) among adolescents in this study was 21% (**Table 3**). Chi-square tests of independence were performed to examine the relationship between undernutrition and selected sociodemographic variables (Table 3). A higher proportion of males than females were undernourished ($P < 0.05$) (Table 3). This association was confirmed in logistic regression models, where males were twice as likely to be undernourished as females regardless of the food security indicator entered in the model and after adjusting for all other covariates ($P < 0.05$) (**Table 4**).

Multivariate analysis of undernutrition. In a logistic regression analysis, undernutrition was associated with age ($P < 0.05$), puberty ($P < 0.05$), and the interaction between age (continuous variable) and puberty (dichotomous) ($P = 0.08$). The interaction suggested that effect of age on undernutrition was moderated by an individual's pubertal status. Other explanatory variables and quadratic transformations of selected explanatory variables were not significant predictors of undernutrition. The removal of selected covariates resulted in minor reductions in the adjusted r^2 and coefficients for indicators of household food security but did not alter coefficients for the remaining variables. Hence, the explanatory variables in the final multivariate analysis were sex, age, puberty, and the interaction term age × puberty.

Separate logistic regression models examined whether each of the food security variables had independent relationships with undernutrition. In these models of the log odds of undernutrition, EnergyAdq and HDDS were significant (Table 4). For every 10 percentage point increase in EnergyAdq, the odds of being undernourished decreased by 7% [OR = 0.93 (95%CI:0.89, 0.99); $P < 0.05$] after controlling for all other covariates in the model (**Fig. 1**; Table 4). Similarly, HDDS was a significant predictor of undernutrition. The consumption of each additional food group at the household level decreased the odds of an adolescent being undernourished by 14% [OR = 0.86 (95%CI: 0.74, 0.99); $P < 0.05$] after controlling for all other covariates in the model (Fig. 1; Table 4). By contrast, CSI was not associated with undernutrition (Fig. 1; Table 4). Additional variations of the coping strategies indicator were generated, including data reduction using factor analysis and a subsample of questions (32), and tested in logistic regression models. We found no significant associations between these reduced CSI variables and undernutrition.

Discussion

We are not aware of any studies that have comprehensively examined the relationship between food security and nutritional outcomes among adolescents in developing countries. This study provides new information on food security and adolescent nutritional health by: *1*) examining correlations between 3 commonly used measures of household food security; *2*) describing the household food security and individual nutrition status of adolescents living in Kilosa District, Tanzania; and *3*) examining household food security and other predictors of undernutrition.

First, using correlation analysis, we were able to demonstrate that EnergyAdeq, HDDS, and CSI described some common aspect of the construct for household food security. It is possible that underreporting of household food intake may have deflated the proportion of households attaining EnergyAdq (45). Despite this possibility, there is consistency across all 3 food security measures considered in this study. The prevalence estimates of each household food security measure presented here are consistent with previous findings in sub-Saharan Africa (3,4,13,46).

TABLE 3 Individual characteristics and prevalence of undernutrition among adolescents in Tanzania[1]

Characteristic	n^2	Undernutrition[3,4]		
		n^2	%	P^3
Overall	670	653	21	
Age				<0.05
10–12 y	255	253	17.8	
13–15 y	303	302	26.2	
16–19 y	99	98	13.3	
Gender				<0.05
Male	363	354	25.4	
Female	307	299	15.7	
Pubertal status				<0.05
Prepubertal	446	436	26.1	
Pubertal	204	200	11.0	
Religion				
Christian	429	427	19.7	
Muslim	173	172	23.3	
Orphan status				
Orphan	83	80	23.8	
Nonorphan	587	573	20.6	
School enrollment				<0.05
Not enrolled	164	161	13.0	
Enrolled	506	492	23.6	
Physical activity level				<0.05
Low/moderate	71	69	30.4	
High	577	562	19.8	
Morbidity[5]				
Healthy	521	508	19.1	
Morbid (>3 symptoms of illness)	70	70	28.6	

[1] Values are *n* or %.
[2] Totals may differ due to missing data on some variables.
[3] Undernutrition defined as BMI-for-age <5th percentile of NCHS/WHO reference (38).
[4] Tests of significance were based on 2-tailed Pearson chi-square, $P < 0.10$, $P < 0.05$.
[5] Morbidity was significant at $P < 0.06$.

TABLE 4 Associations between log odds of undernutrition and each measure of household food security among adolescents (10–19 y) from Kilosa District, Tanzania[1]

	Model 1		Model 2		Model 3		Unadjusted model[2]	
Food security indicators	Coefficient (SE)	*P*	Coefficient (SE)	*P*	Coefficient (SE)	*P*	Coefficient (SE)	*P*
n	559		634		597			
EnergyAdq (1 unit = 10 percentage points)	−0.08 (0.03)	<0.05					−0.07 (0.03)	<0.05
HDDS			−0.15 (0.08)	<0.05			−0.15 (0.07)	<0.05
CSI					0.001 (0.04)		−0.01 (0.03)	
Covariates								
Age (centered)	0.32 (0.08)	<0.05	0.31 (0.07)	<0.05	0.33 (0.07)	<0.05	−0.01 (0.04)	
Puberty	−1.70 (0.50)	<0.05	−1.61 (0.48)	<0.05	−1.55 (0.50)	<0.05	−1.05 (0.25)	<0.05
Male	0.76 (0.23)	<0.05	0.67 (0.21)	<0.05	0.62 (0.22)	<0.05	0.60 (0.20)	<0.05
Age (centered) x puberty[3]	−0.30 (0.17)		−0.27 (0.15)		−0.32 (0.16)	<0.05	−1.05 (0.25)	<0.05
Constant	−1.11 (0.20)	<0.05	−1.08 (0.18)	<0.05	−1.01 (0.29)	<0.05		
Pseudo R^2		0.15		0.14		0.13	N/A	

[1] Significance assessed by $P < 0.05$. CSI, coping strategies index; EnergyAdq, household energy adequacy per adult equivalent; HDDS, household dietary diversity score.
[2] The unadjusted model presents coefficients for the bivariate associations between undernutrition and each variable in the model.
[3] The interaction term age (centered) × puberty was significant at $P < 0.10$ for EnergyAdeq and HDDS.

This study finds that food security indicators reflect general patterns of poverty. In addition, it corroborates previous research reporting poor correlations between anthropometric status and conventional indicators of food security (30,47). Based on our analysis, we find that linear relationships, which are well captured in correlation analysis, do not aptly describe the dynamic and sometimes nonlinear relationships observed between measures of food security and undernutrition (Fig. 1).

Second, estimates of undernutrition in this sample were similar to previous estimates among adolescents in sub-Saharan Africa (5–8). Notably, adolescents in this study experienced undernutrition at a rate similar to children <5 y (17%), a considerably more vulnerable subgroup of the Tanzanian population (2). This supports the argument that poor nutritional health may persist from childhood into adolescence (48). The particularly high prevalence of undernutrition among adolescent males may be related to differences in growth and sexual development, combined with increased dietary requirements and energy expenditure (49). This study corroborates earlier findings that older adolescents have lower rates of undernutrition compared with younger adolescents (6,8). In addition, this study measured the interactions between pubertal status and age as explanatory variables for undernutrition among adolescents.

Clinical assessments of sexual maturation provide rigorous evaluation of pubertal stages (42,50). However, such assessments in community-based settings depend on well-trained clinicians, appropriate facilities for assessment, and cultural acceptability (42). Based on this study's assessment of puberty, which provides only a rough estimate of pubertal attainment, and its cross-sectional design, our results offer only a partial examination of the influence of pubertal attainment on the relationship between age and nutritional status (40,42,50).

Third, although our research design limits the ability to establish causality, the associations presented in this study provide valuable insights on the predictive capacity of dietary measures of food security for adolescent nutritional risk. Whereas some studies have found positive associations between food security and child nutritional status (10–12,51), others have not (52,53). This analysis confirms that risk for undernutrition appears to be lower for adolescents living in households with greater EnergyAdq and dietary diversity but finds no association between risk for undernutrition and coping strategies (Fig. 1; Table 4). The CSI describes the strategies that households employ to cope with food shortage; these strategies may buffer or protect adolescents from undernutrition (13). Furthermore, coping strategies were assessed based on a 30-d recall, whereas both the EnergyAdeq and HDDS were derived from a single 24-h recall per household. The difference in time horizons may also explain the variation in the predictive capacity of CSI for undernutrition.

This study contributes to a rapidly expanding literature on food security issues in developing countries. Another approach to food security measurement, the HFIAS, was developed in response to the demand for a universal tool to assess household food security in developing countries (30–34). By assessing food access and experiences of hunger at the household level, the HFIAS and HFSSM capture a greater proportion of the construct of food security. However, they are limited in detailing the relationship between household dietary consumption patterns and nutritional status (46). Income-based measures provide an alternative method for evaluating food access and poverty, but these are cumbersome to collect (34) and, as discussed earlier, poorly correlated with nutritional status. The strong associations between dietary-based measures of food security and undernutrition observed in this study lend support for the inclusion of such measures in research on social determinants of poor nutritional health. Finally, indicators that measure the food security status of individuals within households have the potential to improve our understanding of intrahousehold food distribution and may be more salient predictors of individual nutritional outcomes than household level indicators (13,54).

Drawing from the results of this cross-sectional study, it is highly plausible that household food security mitigates poor nutritional status, thus protecting adolescents from the negative effects of undernutrition on cognitive development, growth, and development. Further research investigating household food security as a protective factor in adolescent health, development, and psychosocial outcomes is recommended. Such research can further our understanding of long-term nutritional health, particularly during the transitions from childhood to adolescence and into adulthood. The results of this study are promising, because they suggest that simple strategies focused on increasing household energy intake and improving dietary diversity among the most vulnerable households could improve the nutritional health of young people.

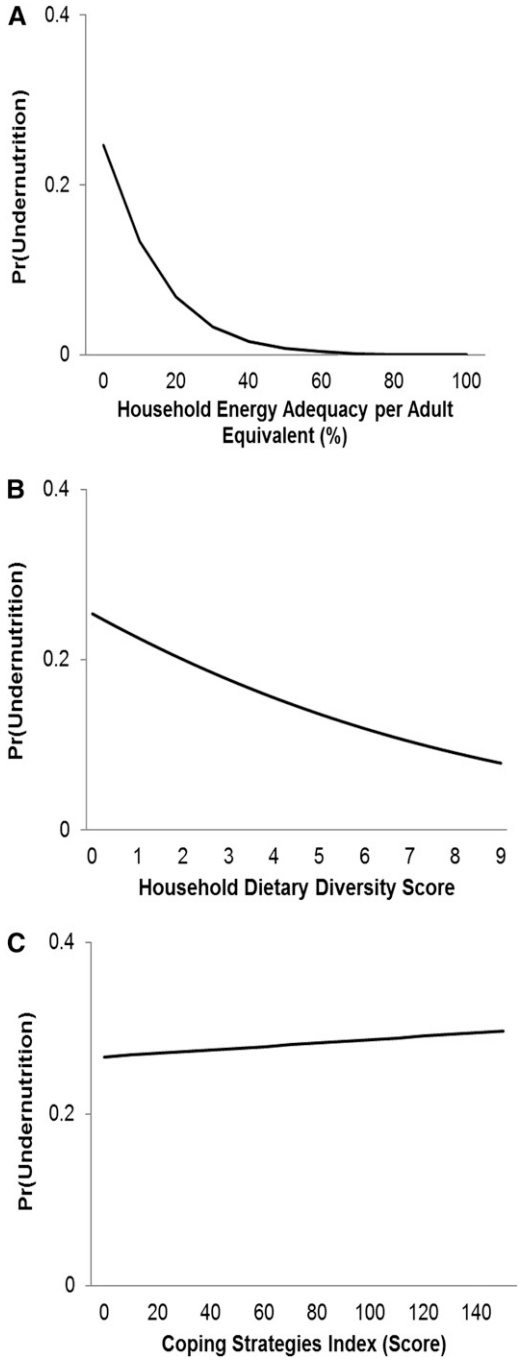

FIGURE 1 Comparison of fitted probabilities of undernutrition among Tanzanian adolescents by EnergyAdq (*A*), HDDS (*B*), and CSI (*C*). EnergyAdq, household energy adequacy per adult equivalent; HDDS, household dietary diversity score; CSI, coping strategies index.

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