Title

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Journal

Maternal and Child Nutrition, 14(2)

ISSN

1740-8695

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Publication Date

2018-04-01

DOI

10.1111/mcn.12543

Peer reviewed

Received: 12 January 2017 | Revised: 13 September 2017 | Accepted: 17 September 2017
DOI: 10.1111/mcn.12543

WILEY Maternal & Child Nutrition

ORIGINAL ARTICLE

Timing, intensity, and duration of household food insecurity are associated with early childhood development in Kenya

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Funding information
National Science Foundation

Abstract

This study examines the association between 3 dimensions of food insecurity (timing, intensity, and duration) and 3 domains of child development (gross motor, communication, and personal social). Longitudinal data from 303 households (n = 309 children) visited 9 times over 2 years were collected. Children in households experiencing severe food insecurity 3 months prior (*timing*) had significantly lower gross motor (β −0.14; 95% CI [0.27, −0.0033]; p = .045), communication (β −0.16; 95% CI [−0.30, −0.023]; p = .023), and personal social (β −0.20; 95% CI [−0.33, −0.073]; p = .002) Z-scores, using lagged longitudinal linear models controlling for current food insecurity; these results were attenuated in full models, which included maternal education, household asset index, and child anthropometry. Children in households that experienced greater aggregate food insecurity over the past 2 years (*intensity*) had significantly lower gross motor (β −0.047; 95% CI [−0.077, −0.018]; p = .002), communication (β −0.042; 95% CI [−0.076, −0.0073]; p = .018), and personal social (β −0.042; 95% CI [−0.074, −0.010]; p = .010) Z-scores; these results were also attenuated in full models. Children with more time exposed to food insecurity (*duration*) had significantly lower gross motor (β −0.050; 95% CI [−0.087, −0.012]; p = .010), communication (β −0.042; 95% CI [−0.086, 0.0013]; p = .057), and personal social (β −0.037; 95% CI [−0.077, 0.0039]; p = .076) Z-scores; these results were no longer significant in full models. Our findings suggest that acute and chronic food insecurity and child development are related, but that many associations are attenuated with the inclusion of relevant covariates.

KEYWORDS
early childhood development, food security, Kenya, Lake Victoria, stunting

1 | INTRODUCTION

Worldwide, 1 in 9 people is food insecure, and most of these people reside in low- and middle-income countries (LMICs; FAO, 2015). Food security is defined as having sustained physical, social, and economic access to sufficient, safe, and nutritious food that meets dietary needs and food preferences (FAO, 1996). Sub-Saharan Africa has both the highest prevalence of food insecurity (FAO, 2015) and the highest percentage of children at risk for developmental delays (Black et al., 2016). Although associations between food insecurity and poor child development in high-income countries show consistent negative effects, little research examines how food insecurity shapes child development in LMICs. Yet failure to meet development milestones has lifelong implications for educational attainment, economic productivity, and chronic health, contributing to the intergenerational nature of food insecurity and suboptimal development (Engle et al., 2007; Engle et al., 2011; Grantham-McGregor et al., 2007; Walker, Chang, Wright, Osmond, & Grantham-McGregor, 2015).

Evidence from high-income countries suggests that food insecurity is negatively associated with child development beyond the effects of poverty. In reviews, food insecurity was associated with suboptimal behavioural and intellectual outcomes independent of poverty status in the United States (Perez-Escamilla & de Toledo Vianna, 2012) and with poor language comprehension, delays in socioemotional, cognitive, and motor development in Canada (Ke & Ford-Jones, 2015). Cross-sectional research in the United States shows food insecurity is associated with mental disorders among children age 4 to 11 years controlling for socio-economic status (Burke, Cayir, Hartline-Grafton,

& Meade, 2016) and poor behavioural and academic functioning among children under age 12 years (Murphy et al., 1998).

In LMICs, there is limited robust research investigating associations between food insecurity and child development and adequately controlling for poverty and relevant confounders. In Bangladesh, household food security was associated with better language comprehension and expression after controlling for socio-economic status (Saha et al., 2010). Food insecurity has also been linked to behaviours and conditions that can affect children's development, including maternal–infant interactions in Bangladesh (Frith, Naved, Persson, Rasmussen, & Frongillo, 2012) and parental depression, poor school functioning, and negative behavioural outcomes in Uganda (Huang, Abura, Theise, & Nakigudde, 2016).

Food insecurity is hypothesized to impact child development through pathways involving insufficient diets, leading to suboptimal growth and poor development (Herman et al., 2014). Undernutrition, illness, and psychosocial stress during the first 1,000 days are frequent causes of developmental deficits (Black et al., 2016) and represent an important pathway through which food insecurity could negatively impact child development. In studies adjusting for socio-economic status, food insecurity has been associated with poor physical growth, including stunting and underweight, in Colombia (Hackett, Melgar-Quiñonez, & Álvarez, 2009), Pakistan (Baig-Ansari, Rahbar, Bhutta, & Badruddin, 2006), Bangladesh (Ali et al., 2013), Nepal (Sreeramareddy, Ramakrishnareddy, & Subramaniam, 2015), Ethiopia (Ali et al., 2013), and pooled analyses across many LMICs (Humphries et al., 2015; Psaki et al., 2012). Several studies in LMICs have further found associations between stunting and poor developmental outcomes. There is strong evidence that the majority of stunting occurs in the first 2 years of life (Victora et al., 2008; Victora, de Onis, Hallal, Blossner, & Shrimpton, 2010) and there are clear biological pathways suggesting causal linkages between linear growth retardation and poor child development. A recent meta-analysis of 68 studies in 29 LMICs found significant cross-sectional and prospective associations between greater height-for-age Z-scores and better cognitive ability, earlier walking age, and higher motor scores (Sudfeld et al., 2015). Moreover, a recent prospective cohort study in Jamaica found that the impact of stunting on development continues in the next generation of children (Walker et al., 2015).

Food security may also impact child development by heightening caregiver stress and thereby influencing responsive and nurturing caregiving (Black et al., 2016; Britto et al., 2016). Further, food insecurity is a risk factor for maternal depression in LMICs (Wachs, 2009). After controlling for socio-economic status, food insecurity was associated with caregiver psychosocial stress in Ethiopia (Hadley, Tessema, & Muluneh, 2012), parental depression in Uganda (Huang et al., 2016), and adverse child mental health in a review of LMICs (Herba, Glover, Ramchandani, & Rondon, 2016). Poor maternal mental health, in turn, has been associated with reduced child stimulation in Jamaica (Baker-Henningham, Powell, Walker, & Grantham-McGregor, 2003), infants' impaired motor development in Bangladesh (Nasreen, Kabir, Forsell, & Edhborg, 2013), and negative impacts on child growth in LMICs (Hurley, Surkan, & Black, 2012).

Effects of food insecurity on child development are likely to vary by child age and development stage. Children under 3 years are particularly vulnerable because of the sensitivity of early brain development and the limited availability of services to children before they reach school age (Black et al., 2016). When considering timing and economic efficiency, antenatal and early childhood interventions may be most beneficial for developmental outcomes (Doyle, Harmon, Heckman, & Tremblay, 2009). A meta-analysis from 24 low-, middle-, and high-income countries further demonstrates this, showing interventions targeting infants and toddlers rather than older children had greater effects (Nores & Barnett, 2010). Due to the vulnerability of young children, household food insecurity that is recent or during critical periods may be associated with developmental outcomes. However, extended periods of food insecurity may worsen impacts on children's development as effects of chronic undernutrition and caregiver stress accumulate over time.

Key messages

- Food insecurity and poor child development are widespread in LMICs and have long-term health implications, yet research on their relation is scarce.
- This 2-year longitudinal study found the timing, intensity, and duration of food insecurity were significantly associated with early childhood development outcomes. Findings suggest that acute and chronic food insecurity may be related to developmental deficits.
- Results highlight the importance of targeted interventions that can prevent and build resilience to food insecurity which may benefit vulnerable children's developmental potential and have intergenerational effects.

About one quarter of Kenya's population is chronically food insecure (FAO, 2015). Communities around Lake Victoria are unable to access food resources due to rising costs (Fiorella et al., 2014; Johnson, 2010). For these reasons, lakeshore communities experience high rates of food insecurity and child malnutrition, including stunting rates of 23% (FAO, 2016; FAO, 2005; Kenya National Bureau of Statistics et al., 2015). Among Mfangano Island communities, 60% of households are moderately or severely food insecure (Fiorella et al., 2014). Since the 1990s, the quantity of fish caught from Lake Victoria has been declining (Abila, 2003; Pauly, Watson, & Alder, 2005). Food insecurity in the Lake Victoria basin is intertwined with an export-oriented fishery, household dependence on fluctuating fish catch (Abila, 2000; Abila, 2003; Fiorella et al., 2014; Nagata et al., 2015), and complex gender dynamics within the fishery (Fiorella et al., 2015; Geheb et al., 2008).

This study aimed to examine the association between the timing, intensity, and duration of household food insecurity and early childhood development. Examining multiple dimensions of food insecurity allowed us to test three hypotheses: (a) greater food insecurity experienced by a household 3 months ago is associated with lower current child development scores, while controlling for current food insecurity, (b) more severe food insecurity over the past 2 years is associated with lower child development scores at the end of the 2 years, and (c) more time being food insecure over the past 2 years is associated with lower child development scores at the end of the 2 years.

2 | METHODS

2.1 | Study site

The study was conducted on Mfangano Island in Nyanza Province, Kenya. Lying within Lake Victoria, Mfangano Island has a population of 21,000 (Mbita Division, 2009). Broadly representative of much of the Lake Victoria region, the island's inhabitants are vulnerable to changes in the lake as fishery involvement for trade and subsistence is widespread (Fiorella et al., 2014). Mfangano Island is rural with no running water or paved roads, and limited electricity and health services.

2.2 | Sampling and data collection

In July 2012, households were selected with stratified random sampling based on the regions of Mfangano Island. The 4 regions bordering the lakeshore (North, South, East, and West) are defined by the Kenyan government, and 2 additional regions––a nearby island (Takawiri) and a community atop a small mountain at the centre of the island (Sokolo)––were separately defined for sampling because of geographic diversity and hypothesized differences in livelihoods. The number of households selected from each region was proportional to its population. Three hundred and three households living on Mfangano Island with at least 1 child under the age of 2 years in residence were enroled. In households with more than 1 child under the age of 2 years, the youngest child was selected to participate; in the case of twins, both were enrolled (n = 309 children, inclusive of twins). Five child deaths, including 1 twin, occurred during the study (2012–2015) and these participants were removed from analyses. Therefore, final results include 299 households and 304 children.

Data were collected from December 2012 to April 2015 as part of a longitudinal panel study on fishing livelihoods, fish consumption, and child nutrition. Participants were located every 3 months for 9 visits. Local enumerators conducted surveys in Dholuo, the regional language. Surveys and data collection tools were developed from validated measures and locally adapted.

2.3 | Study variables

The Household Food Insecurity Access Scale (HFIAS) was used to measure household food insecurity (Coates, Swindale, & Bilinski, 2007). The scale is widely utilized internationally and has been validated in several LMICs (Coates, Wilde, Webb, Rogers, & Houser, 2006; Desiere, D'Haese, & Niragira, 2015; Gebreyesus, Lunde, Mariam, Woldehanna, & Lindtjørn, 2015; Knueppel, Demment, & Kaiser, 2010; Maes, Hadley, Tesfaye, Shifferaw, & Tesfaye, 2009). The HFIAS has also been correlated with indicators of poverty and food consumption in various contexts (Becquey et al., 2010; Coates et al., 2006; Knueppel et al., 2010; Maes et al., 2009). The HFIAS and similar experience-based measures of household food security are robust indicators of food access (Leroy, Ruel, Frongillo, Harris, & Ballard, 2015). The HFIAS includes 9 questions about food access, quantity, and quality over the previous 30 days and was administered to households every 3 months (9 times in total). Questions were scored from 0 to 3 depending on whether the respondent experienced the described condition never (0 times), rarely (1–2 times), sometimes (3–10 times), or often (>10 times). Food insecurity scores were calculated by summing each household's responses to the 9 HFIAS questions at each time point and dividing scores by 10 for ease of interpretation. Scores at each time point range from 0 (*least food insecure*) to 2.7 (*most food insecure, maximum possible value*).

Three variables assessing different dimensions of household food insecurity were created using the HFIAS scores: timing, intensity, and duration. *Timing* values are the raw scores at each time point. The *intensity* of food insecurity was calculated as each household's cumulative score across all 9 time points over the 2-year study, ranging from 0 (*least food insecure*) to 24.3 (*most food insecure, maximum possible value*). The *duration* of food insecurity was quantified as the number of times (of the 9 time points) throughout the 2-year study that a household had a food insecurity score in the top quartile (most severely food insecure). The duration variable of food insecurity ranges from 0 to 9 times.

Subscales of the Ages and Stages Questionnaire: Inventory (ASQ:I) were used to assess 3 domains of child development: gross motor, communication, and personal social (Squires, Bricker, & Clifford, 2011). Child development was assessed every 6 months at follow-up visits during every other 3-month intervals, for 5 times. The ASQ:I is a modified version of the Ages and Stages Questionnaire, which is widely used for the developmental screening of children under 5 years of age (Filipek et al., 2000; Kerstjens et al., 2009; Rydz et al., 2006) and has been used in LMICs (Fernald, Kariger, Hidrobo, & Gertler, 2012). The questionnaires contain a series of age-specific items assessing the achievement of developmental milestones and tracking the child's progress.

The gross motor subscale evaluates body and muscle movement, including tasks such as standing, walking, and balancing. The communication subscale assesses language development and the use of words or sounds to express feelings. The personal social subscale reflects emotional responses and social interactions. Subscale scores ranged from 0 to 126, 0 to 130, and 0 to 158 on the gross motor, communication, and personal social subscales, respectively. As the ASQ:I questions are designed to continue being asked until a child's threshold is met, the number of questions asked and the maximum value varies with a child's ability and age. Consequently, we calculated continuous scores for each subscale and converted them to Z-scores based on this population at 2-month age intervals. The ASQ:I was translated and adapted for our study by using local culturally appropriate items, examples, and tasks, but no substantial changes were made to the original questionnaires.

The 5 Ages and Stages Questionnaire subscales (gross motor, communication, personal social, fine motor, and problem solving) were piloted to assess respondent bias, maternal accuracy in reporting children's abilities, cultural appropriateness, and feasibility according to standard procedures (Fernald, Kariger, Engle, & Raikes, 2009).

Piloting entailed asking mothers about their child's abilities and then having children demonstrate their skills. Gross motor, communication, and personal social subscale responses were most accurate, valid, and feasible to administer in the field. The fine motor and problem solving subscales were not included because they were more difficult to measure in younger infants, had the greatest maternal recall bias, and were most challenging to locally adapt.

Demographics, including household size (number of members) and maternal education (categorized into: none or some primary school and completed primary school or beyond) were assessed at baseline, 12 months and 24 months. Annual measures were used as these variables were not expected to change more frequently.

Household socio-economic status was assessed with an asset index created from the first principal component of a principal component analysis (including assets such as housing composition, electricity, toilet facilities, and ownership of clock, radio, camera, computer, television, phone, refrigerator, land, livestock, solar lighting, and furniture). This approach has been shown to be a good proxy for household wealth and was correlated with consumption expenditures (Faulkingham & Namazie, 2002; Filmer & Pritchett, 1999, 2001).

Anthropometric measurements, including weight and length/height for each child were taken every 3 months (9 times in total) using standard techniques (Cogill, 2003; WHO, 2006). Weight was measured using Seca digital scales (Seca 803 Digital Floor Scale; Seca Ltd., Chino, CA, USA). Length (children <24 months) was measured using infantometers (Seca 417 Mobile Infantometer; Seca Ltd., Chino, CA, USA), and height (children >24 months) was measured using stadiometers (Seca 213 Mobile Stadiometer; Seca Ltd., Chino, CA, USA). Standardized Z-scores for length/height-for-age (LAZ/HAZ) and weight-for-age (WAZ) were calculated to assess child growth according to WHO child growth standards (WHO, 2006). Children were classified as stunted (LAZ/HAZ < −2) or underweight (WAZ < −2).

2.4 | Statistical analyses

All statistical analyses were conducted in Stata 14. Three regression models were constructed for each child development subscale: gross motor, communication, and personal social, with the timing, intensity, and duration dimensions of food insecurity used alternately as independent variables. The first model was comprised of child-level covariates, including child age in months and child sex. In the second model, time-invariant household-level variables such as household size, assets, and maternal education were added. In the third model, child stunting and underweight status were added. Regions did not influence results; hence, they were not included in the final models.

The large number of data collection rounds enabled us to replace missing values with existing data. For variables that changed between time points, such as child age and nutritional status, we used a participant's average across proximate time points to fill in missing data. These updates were necessary in less than 10% of cases for all variables.

The associations between food insecurity timing and child development subscales were assessed using longitudinal linear multivariate generalized estimating equation (GEE) models. Marginal GEE models were used to compute population-average effects allowing for longitudinal changes. Marginal GEE models were chosen over random or mixed effects models because describing how means change in populations of individuals as covariates/explanatory variables change is more relevant for policies and programmes, and GEE models allowed for the use of robust standard errors and flexible correlation structures (Hubbard et al., 2010). Correlated data (numerous visits per household or child) were accounted for using an exchangeable correlation structure. Other correlation structures produced similar results, and this structure was chosen because there were multiple measurements on the same child and each child came from an independent household. A lagged food insecurity variable was created to estimate the effect of household food insecurity 3 months ago on current gross motor, communication, and personal social Z-scores. All models include ASQ:I scores from 4 data collection rounds (6-, 12-, 18-, and 24-month follow-up) and corresponding lagged food insecurity scores from 3 months prior to each round, while controlling for current household food insecurity scores.

The association between food insecurity intensity and duration and child development subscales were assessed with linear multivariate regression models. Food insecurity intensity and duration are cumulative measures over the entire 2-year study and were therefore examined in relation to child development Z-scores at the final data collection round. Stunting and underweight status are defined in these analyses as the aggregate number of times a child was stunted or underweight during the past 2 years to capture nutritional status over the study period.

2.5 | Ethics

The study was approved by the University of California, Berkeley Institutional Review Board and the Kenya Medical Research Institute Ethical Review Committee. Adult participants provided written consent for themselves and their children prior to enrolment.

3 | RESULTS

Mean household size was 6 and 52% of mothers had not completed primary school (Table 1). The mean age of children at baseline was 12 months, ranging from 1 to 26 months, and children were 24 to 51 months at the last follow-up visit. Five children were over 24 months at baseline despite selection criteria due to the time period between enrolment and baseline data collection. At baseline, the prevalence of stunting was 15% among children under 12 months of age, peaked among children 18 to 23 months of age (34%), and reduced among children over 36 months (25%). At baseline, the underweight prevalence was low (3–11%) but greater among children 12 months of age and older; at follow-up visits, the underweight prevalence was higher among younger children.

The mean food insecurity score (*timing*) did not substantially change across time points (ranging from 0.94 in Round 1 to 0.80 in Rounds 6, 7, and 8), although there was a wide range of scores (Table 1). Food insecurity scores within households did not greatly

TABLE 1 Sociodemographic and anthropometric characteristics of study population and household food insecurity timing, intensity, and duration

		Mean ± *SD* or *N* (%) (*n* = 304)
Household	Household size[a]	6 ± 2
	Asset index[a,b]	0.00 ± 1.66
Maternal	Maternal education (highest level attained)[a]	
	None or primary not completed	155 (52)
	Completed primary or beyond	144 (48)
Child	Child age at baseline (months)	12 ± 7
	Child sex (male)	146 (48)
	Stunted[c] at round 1 (baseline)	
	Age < 12 months	24 (15)
	Age ≥ 12 months	40 (28)
	Underweight[d] at round 1 (baseline)	
	Age < 12 months	14 (9)
	Age ≥ 12 months	15 (11)
	Stunted at round 5 (12 month follow-up)	
	Age < 24 months	50 (30)
	Age ≥ 24 months	43 (31)
	Underweight at round 5 (12 month follow-up)	
	Age < 24 months	16 (10)
	Age ≥ 24 months	9 (6)
	Stunted at round 9 (24 month follow-up)	
	Age < 36 months	42 (26)
	Age ≥ 36 months	36 (25)
	Underweight at round 9 (24 month follow-up)	
	Age < 36 months	13 (8)
	Age ≥ 36 months	4 (3)
Food insecurity	Food insecurity timing[e]	
	Round 1[f]	0.94 ± 0.51
	Round 2	0.88 ± 0.46
	Round 3	0.81 ± 0.44
	Round 4	0.83 ± 0.40
	Round 5	0.83 ± 0.43
	Round 6	0.80 ± 0.45
	Round 7	0.80 ± 0.41
	Round 8	0.80 ± 0.44
	Round 9	0.84 ± 0.47
	Food insecurity intensity[g]	
	Cumulative 24 months	7.54 ± 2.98
	Food insecurity duration[h]	
	Never	107 (35)
	1–2 times	101 (33)
	3–4 times	47 (15)
	5–6 times	28 (9)
	≥7 times	21 (7)

[a]*n* = 299 households as 5 twins participated in the study. Baseline values as variables are time-invariant.

[b]Derived by use of principal components, includes housing construction (roof and floor), electricity, toilet, and ownership of clock, radio, camera, computer, television, phone, refrigerator, land, livestock, solar lighting, and furniture (bed, cabinet, and sofa).

[c]Height-for-age Z-score < −2.

[d]Weight-for-age Z-score < −2.

[e]Scores range from 0 to 2.7 and are the sum of Household Food Insecurity Access Scale (HFIAS) question responses; higher scores are indicative of greater food insecurity.

[f]Rounds represent 3-month data collection periods.

[g]Scores range from 0 to 24.3 and are the sum of scores at all 9 data collection rounds spanning 24 months; higher scores are indicative of greater food insecurity.

[h]Number of times a household is severely food insecure (bottom 25th percentile of intensity food insecurity scores) during 9 data collection rounds over 24 months.

fluctuate over time as there was more variability in food insecurity scores between households. Food insecurity intensity over the 2 years was moderate (mean = 7.54 ± 2.98). The majority of households (68%) experienced severe food insecurity less than 3 times (*duration*), but nearly one quarter of households experienced severe food insecurity for at least 1 year (half of the study duration).

3.1 | Associations between food insecurity and child development

3.1.1 | Timing

Table 2 presents the association between the timing of food insecurity over 24 months and child development. Children in households that experienced food insecurity 3 months prior had significantly lower gross motor (β −0.14; 95% CI [−0.27, −0.0033]), communication (β −0.16; 95% CI [−0.30, −0.023]), and personal social (β −0.20; 95% CI −0.33, −0.073]) Z-scores when controlling for current food insecurity status and child demographics (Model 1). With the addition of the socio-economic (Model 2) and anthropometric (Model 3) variables, food insecurity 3 months prior remained significantly negatively associated with communication and personal social subscales; the coefficient did not remain significant for the gross motor subscale, however.

Maternal education and asset index scores were consistently significantly positively associated with all the 3 child development subscales (Models 2 and 3). Children whose mothers completed primary school or beyond and who lived in wealthier households had higher gross motor, communication, and personal social Z-scores. Stunting (β −0.29; 95% CI [−0.42, −0.17]) and underweight (β −0.42; 95% CI [−0.69, −0.15]) were significant in gross motor analyses (Model 3) demonstrating that stunted and underweight children had lower gross motor Z-scores. Stunting was also negatively associated with communication (β −0.27; 95% CI [−0.42, −0.13]) and personal social (β −0.27; 95% CI [−0.38, −0.15]) Z-scores (Model 3). These results suggest that

TABLE 2 Association between food insecurity timing[a] and child development Z-scores over 24 months controlling for child characteristics (Model 1), household demographics (Model 2), and child nutritional status (Model 3)[b]

	Model 1[c] β [95% CI] (*n* = 304)	Model 2[c, d] β [95% CI] (*n* = 304)	Model 3[c, d] β [95% CI] (*n* = 304)
Gross motor			
Food insecurity 3 months ago	−0.14 [−0.27, −0.0033]**	−0.10 [−0.24, 0.032]	−0.097 [−0.23, 0.036]
Food insecurity current	−0.083 [−0.21, 0.043]	−0.051 [−0.18, 0.075]	−0.050 [−0.18, 0.079]
Child sex (1 = male)	−0.045 [−0.19, 0.10]	−0.033 [−0.18, 0.11]	−0.015 [−0.15, 0.12]
Maternal education (1 = completed primary or beyond)		0.21 [0.069, 0.36]***	0.20 [0.065, 0.33]***
Asset index (standardized scores)		0.046 [−0.0045, 0.097]*	0.044 [−0.0039, 0.092]*
Stunted (1 = HAZ < −2)			−0.29 [−0.42, −0.17]***
Underweight (1 = WAZ < −2)			−0.42 [−0.69, −0.15]***
Communication			
Food insecurity 3 months ago	−0.16 [−0.30, −0.023]**	−0.12 [−0.27, 0.017]*	−0.12 [−0.26, 0.019]*
Food insecurity current	−0.052 [−0.19, 0.086]	−0.013 [−0.15, 0.12]	−0.0070 [−0.14, 0.13]
Child sex (1 = male)	−0.19 [−0.35, −0.028]**	−0.18 [−0.34, −0.019]**	−0.17 [−0.32, −0.014]**
Maternal education (1 = completed primary or beyond)		0.19 [0.030, 0.35]**	0.18 [0.024, 0.33]**
Asset index (standardized scores)		0.070 [0.012, 0.13]**	0.069 [0.012, 0.13]**
Stunted (1 = HAZ < −2)			−0.27 [−0.42, −0.13]***
Underweight (1 = WAZ < −2)			−0.10 [−0.31, 0.11]
Personal social			
Food insecurity 3 months ago	−0.20 [−0.33, −0.073]***	−0.17 [−0.30, −0.036]**	−0.16 [−0.29, −0.031]**
Food insecurity current	−0.0049 [−0.15, 0.14]	0.028 [−0.11, 0.17]	0.032 [−0.11, 0.18]
Child sex (1 = male)	−0.17 [−0.33, −0.18]**	−0.16 [−0.31, −0.011]**	−0.15 [−0.30, −0.0048]**
Maternal education (1 = completed primary or beyond)		0.14 [−0.011, 0.30]*	0.13 [−0.018, 0.28]*
Asset index (standardized scores)		0.063 [0.0056, 0.12]**	0.062 [0.0060, 0.12]*
Stunted (1 = HAZ < −2)			−0.27 [−0.38, −0.15]***
Underweight (1 = WAZ < −2)			−0.16 [−0.38, 0.062]

[a]Linear scores at each time point.

[b]Generalized Estimating Equations models employed with 4 time points included at 6-month intervals.

[c]Controlled for child age.

[d]Controlled for household size.

*$p < .1$;

**$p < .05$;

***$p < .01$.

linear growth retardation may be on the pathway from food insecurity timing to child development.

3.1.2 | Intensity

Table 3 presents the association between the intensity of food insecurity over 24 months and child development. Children in households that were more intensely food insecure (cumulative food insecurity score) over the past 2 years had significantly lower gross motor (β −0.047; 95% CI [−0.077, −0.018]), communication (β −0.042; 95% CI [−0.076, −0.0073]), and personal social (β −0.042; 95% CI [−0.074, −0.010]) Z-scores (Model 1). These associations remained significant with the inclusion of socio-economic covariates (Model 2) and anthropometric measures (Model 3) for the gross motor subscale but not for the communication or personal social subscale.

Maternal education was significantly positively associated with all child development subscales (Models 2 and 3). Stunting was consistently significantly negatively associated with child development Z-scores (gross motor: β −0.077; 95% CI [−0.10, −0.048]; communication: β −0.053; 95% CI [−0.086, −0.019]; personal social: β −0.056; 95% CI [−0.087, −0.024]; Model 3). Underweight children also had significantly lower communication Z-scores (β −0.065; 95% CI [−0.12, −0.0045]; Model 3).

3.1.3 | Duration

Table 4 presents the association between the duration of food insecurity over 24 months and child development. The duration of food insecurity (number of times food insecure in previous 2 years) was significantly negatively associated with all the 3 child development subscales (Model 1). The greater amount of time a household experienced severe food insecurity over the past 2 years, the lower a child's development Z-scores were. Specifically, findings were significant at the $p < .05$ level for gross motor Z-scores (β −0.050; 95% CI [−0.087, −0.012]) and were significant at the $p < .1$ level for communication (β −0.042; 95% CI [−0.086, 0.0013]), and personal social (β −0.037;

TABLE 3 Association between food insecurity intensity[a] and child development Z-scores over 24 months controlling for child characteristics (Model 1), household demographics (Model 2), and child nutritional status (Model 3)[b]

	Model 1[c] β [95% CI] (*n* = 304)	Model 2 [c,d] β [95% CI] (*n* = 304)	Model 3 [c,d] β [95% CI] (*n* = 304)
Gross motor			
Food insecurity	−0.047 [−0.077, −0.018]***	−0.030 [−0.062, 0.0010]*	−0.028]−0.058, 0.0019]*
Child sex (1 = male)	−0.026 [−0.20, 0.15]	−0.017 [−0.19, 0.16]	0.010 [−0.15, 0.17]
Maternal education (1 = completed primary or beyond)		0.24 [0.063, 0.42]***	0.20 [0.035, 0.37]**
Asset index (standardized scores)		0.042 [−0.014, 0.098]	0.037 [−0.016, 0.089]
Stunted[e]			−0.077 [−0.10, −0.048]***
Underweight[e]			−0.0044 [−0.055, 0.046]
Communication			
Food insecurity	−0.042 [−0.076, −0.0073]**	−0.025 [−0.062, 0.012]	−0.022 [−0.057, 0.014]
Child sex (1 = male)	−0.24 [−0.44, −0.034]**	−0.23 [−0.43, −0.027]**	−0.21 [−0.40, −0.013]*
Maternal education (1 = completed primary or beyond)		0.18 [−0.031, 0.39]*	0.15 [−0.055, 0.35]
Asset index (standardized scores)		0.056 [−0.0095, 0.12]*	0.051 [−0.012, 0.11]
Stunted[e]			−0.053 [−0.086, −0.019]***
Underweight[e]			−0.065 [−0.12, −0.0045]**
Personal social			
Food insecurity	−0.042 [−0.074, −0.010]**	−0.023 [−0.057, 0.011]	−0.021 [−0.054, 0.012]
Child sex (1 = male)	−0.24 [−0.43, −0.053]**	−0.23 [−0.42, −0.044]**	−0.21 [−0.39, −0.028]**
Maternal education (1 = completed primary or beyond)		0.24 [0.050, 0.43]**	0.21 [0.027, 0.40]**
Asset index (standardized scores)		0.055 [−0.0047, 0.12]*	0.051 [−0.0072, 0.11]*
Stunted[e]			−0.056 [−0.087, −0.024]***
Underweight[e]			−0.00036 [−0.057, 0.056]

[a]Linear scores, sum of HFIAS scores at all 9 data collection rounds over 24 months, defined as cumulative severity of food insecurity.

[b]Linear multivariate regression models assessing the association between food insecurity intensity and child development scores at the end of the 2-year study.

[c]Controlled for child age.

[d]Controlled for household size.

[e]Count variables, number of times child was stunted (HAZ < −2) or underweight (WAZ < −2) over 2-year study, range 0–9 times.

*$p < .1$;

**$p < .05$;

***$p < .01$.

TABLE 4 Association between food insecurity duration[a] and child development Z-scores over 24 months controlling for child characteristics (Model 1), household demographics (Model 2), and child nutritional status (Model 3)[b]

	Model 1[c] β [95% CI] (*n* = 304)	Model 2[c, d] β [95% CI] (*n* = 304)	Model 3[c, d] β [95% CI] (*n* = 304)
Gross motor			
Food insecurity	−0.050 [−0.087, −0.012]**	−0.032 [−0.071, 0.0061]*	−0.029 [−0.066, 0.0075]
Child sex (1 = male)	−0.025 [−0.20, 0.15]	−0.015 [−0.19, 0.16]	0.012 [−0.15, 0.18]
Maternal education (1 = completed primary or beyond)		0.25 [0.077, 0.43]***	0.22 [0.048, 0.38]***
Asset index (standardized scores)		0.048 [−0.0065, 0.10]*	0.042 [−0.0090, 0.094]
Stunted[e]			−0.077 [−0.11, −0.049]***
Underweight[e]			−0.0028 [−0.053, 0.048]
Communication			
Food insecurity	−0.042 [−0.086, 0.0013]*	−0.025 [−0.070, 0.020]	−0.020 [−0.063, 0.024]
Child sex (1 = male)	−0.24 [−0.44, −0.033]**	−0.23 [−0.43, −0.026]**	−0.21 [−0.40, −0.013]**
Maternal education (1 = completed primary or beyond)		0.19 [−0.018, 0.40]*	0.16 [−0.042, 0.36]
Asset index (standardized scores)		0.061 [−0.0026, 0.12]*	0.056 [−0.0047, 0.12]*
Stunted[e]			−0.053 [−0.087, −0.019]***
Underweight[e]			−0.064 [−0.12, −0.0033]**
Personal social			
Food insecurity	−0.037 [−0.077, 0.0039]*	−0.017 [−0.059, 0.025]	−0.015 [−0.055, 0.026]
Child sex (1 = male)	−0.24 [−0.43, −0.053]**	−0.23 [−0.42, −0.044]**	−0.21 [−0.40, −0.029]**
Maternal education (1 = completed primary or beyond)		0.26 [0.065, 0.45]***	0.23 [0.041, 0.41]**
Asset index (standardized scores)		0.062 [0.0036, 0.12]**	0.059 [0.00091, 0.12]*
Stunted[e]			−0.056 [−0.088, −0.024]***
Underweight[e]			0.00028 [−0.056, 0.057]

[a]Count variable, number of times a household is severely food insecure (bottom 25th percentile of intensity food insecurity scores) during 9 data collection rounds over 24 months.

[b]Linear multivariate regression models assessing the association between food insecurity duration and child development scores at the end of the 2-year study.

[c]Controlled for child age.

[d]Controlled for household size.

[e]Count variables, number of times child was stunted (HAZ < −2) or underweight (WAZ < −2) over 2-year study, range 0–9 times.

*$p < .1$;

**$p < .05$;

***$p < .01$.

95% CI [−0.077, 0.0039]) Z-scores. Across all child development subscales, associations with food insecurity duration were attenuated in models including maternal education, household assets, and child malnutrition.

Maternal education and asset index scores were significantly positively associated with food insecurity duration (Model 2). Stunting was significantly associated with child development in all subscale analyses (gross motor: β −0.077; 95% CI [−0.11, −0.049]; communication: β −0.053; 95% CI [−0.087, −0.019]; personal social: β −0.056; 95% CI [−0.088, −0.024]; Model 3). Similar to food insecurity intensity findings, underweight status was also significant (β −0.064; 95% CI [−0.12, −0.0033]) in communication subscale analyses (Model 3).

4 | DISCUSSION

The timing, intensity, and duration of household food insecurity were significantly associated with 3 domains of children's development (gross motor, communication, and personal social); these associations were often attenuated with the inclusion of household- and child-level variables. Food insecurity 3 months in the past (*timing*) was negatively associated with current child development subscale Z-scores. Children in households with more severe food insecurity (*intensity*) had lower gross motor, communication, and personal social Z-scores. Longer household food insecurity (*duration*) was also associated with poorer child development. As expected, maternal education and household assets were positively associated with child development and child malnutrition, measured through stunting and underweight, was negatively associated with child development.

Our results suggest that considering the multidimensionality of food insecurity allows us to better understand both the pathways of impact on child development and its potential for use as an early warning of child development concerns. Food insecurity timing is a measure of acute food insecurity, and intensity and duration are indicators of chronic food insecurity. These differences are further reflected in the different time frames over which they were measured, with timing assessed by food insecurity in the previous 3 months and intensity and duration assessed over the previous 2 years.

Although conceptually different, food insecurity intensity and duration are correlated (R^2 = .85) and show similar patterns of associations with child development scores. The larger coefficients in models assessing food insecurity timing suggest that recent experiences of food insecurity may be particularly important in proximate changes in child development scores. Critically, short-term food insecurity, measured through the timing variable, was significantly associated with child development independent of the association with child growth and household socio-economic status, suggesting that food insecurity may have immediate consequences for child development. Such outcomes may result from restrictions on food access and consumption that may not yet be observable in anthropometric indicators as well as the psychosocial consequences that affect care for children and increase stress within food insecure households.

By examining the extent to which metrics of poverty, including maternal education and household assets, and anthropometry alter relations between food insecurity and child development, we explore multiple pathways of impact. The consistent significance of stunting suggests that a pathway from food insecurity to restricted food access may be particularly important in shaping child development in the long term. The role of maternal education in child development is further suggestive of pathways from food insecurity to maternal stress, care, and knowledge. Household assets play a strong role in child development in food insecurity timing models suggesting that in the short term household socio-economic status may provide a more robust buffer against food insecurity.

The present study has several strengths. Assessing 3 dimensions of household food insecurity (timing, intensity, and duration) and multiple domains of child development provides for a unique understanding of the ways food insecurity shapes child development and yields consistent results in the direction and magnitude of associations. Using 9 measurements of food insecurity over 2 years enabled analyses to account for seasonality, understand households' shifting experiences of food insecurity, and assess anthropometric measurements and child development scores during children's critical period of growth and development. The inclusion of socio-economic status provides further evidence of the importance of food insecurity beyond poverty. Finally, building models by systematically adding variables to analyses allowed for an extensive evaluation of how food insecurity can affect child development as well as the potential pathways of impact.

Household food insecurity and child development are complex, and our study is limited by the definitions and measures of each. The HFIAS primarily focuses on food insecurity access, failing to capture other aspects of food insecurity such as food availability, utilization, nutrition, intrahousehold allocation, and feeding practices and may be subject to recall bias and subjectivity (Coates et al., 2007; Webb et al., 2006). Bias may also be present in child development measures, which rely on caregiver report, although demonstrations of ASQ:I items were facilitated to reduce this concern. Other variables related to food insecurity and child development, such as dietary intake, caregiver mental health, and elements of childcare, and additional domains of child development were not included in these analyses yet may contribute to these relations. Finally, although the study population is comparable to others in rural areas of LMICs, the results may not be generalizable beyond the study population or may be affected by the isolation of the island. Causal interpretations cannot be made, but the longitudinal data collected at multiple time points allowed for rigorous analyses.

Household food insecurity in the study population was widespread and reflects similar findings of food insecurity in Kenya and Lake Victoria communities (FAO, 2015; Kenya National Bureau of Statistics et al., 2015). The prevalence of underweight and stunted children in this study population were comparable to national, rural, and Nyanza Province values (Kenya National Bureau of Statistics et al., 2015), suggesting these results may have broad analogues in communities experiencing similar rates of food insecurity and malnutrition. Results highlight that not only chronic but also acute household food insecurity is associated with a variety of domains of development in early childhood. The significant associations found between food insecurity and child development outcomes confirms past findings (Cook et al., 2004; Saha et al., 2010). Part of this association may occur through a pathway of chronic malnutrition, which is observed in previous studies in LMICs examining food insecurity and stunting among children under age 5 (Psaki et al., 2012). Linear growth retardation as a potential mechanism in our analyses is corroborated by research reporting stunting as a predictor of various developmental outcomes (Black et al., 2016; Walker et al., 2011; Walker et al., 2013).

Food insecurity and poor child development are widespread throughout LMICs. Appreciating how the timing, intensity, and duration of food insecurity negatively relate to child development can help us better address and mitigate these associations. Findings regarding the immediacy of effects of food insecurity on child development suggests the potential for food insecurity metrics to be an early indicator of poor outcomes. Moreover, our results illustrate the need for policies and programming that specifically integrate child development within food insecure communities to address and mitigate deleterious effects.

This study also highlights the importance of recognizing food security and its effects as multidimensional. Understanding the effects of food insecurity as static or even seasonal may be insufficient to appreciate the ways it shapes household outcomes and opportunities to effectively intervene. Moreover, rural households' food security is often closely tied to their dependency on local natural resources for food and income. Rapid and widespread environmental changes in sensitive regions (i.e., freshwater fisheries) continue to threaten sustained food security and make a multidimensional understanding of food insecurity more relevant. Seasonal, climatic, and political threats to food insecurity thus have the potential to affect not only household food insecurity and nutrition but may forebode short-term and, ultimately, long-term effects on child development.

By assessing multiple dimensions of food insecurity, future research can provide a more comprehensive understanding of its effects on child development and other household outcomes. The effects of food insecurity on child development can be further understood by assessing additional domains of child development and evaluating potential mediators, particularly the role of parental care and child diet. Additional research can inform targeted interventions that prevent and build resilience to food insecurity which may benefit children's developmental potential and have intergenerational effects. Nutrition-sensitive food security programmes (Ruel & Alderman, 2013) can also incorporate child development. Overall, interventions integrating food insecurity, malnutrition, and development risks that vulnerable children face early in life can reduce economic and health inequities (Black et al., 2016; Black & Dewey, 2014; Engle et al., 2011).

5 | CONCLUSION

A more complete understanding of the consequences of food insecurity is critical and more comprehensively analysing multiple dimensions of food insecurity can improve our understanding of its consequences. Our findings suggest food insecurity has short- and long-term implications for child development and thus preventing and building resilience to even temporary food insecurity remains urgent. Acute and chronic household food insecurity may impact early childhood development through a pathway of linear growth retardation suggesting that sustainable integrated interventions could have multifaceted benefits. For the hundreds of millions of people in LMICs who are food insecure, improving food security is paramount for enabling vulnerable children to meet their full potential and forestalling the compounding, adverse effects of food insecurity and poor development across generations.

ACKNOWLEDGMENTS

The authors thank the Mfangano Island community members who participated in this study for sharing their experiences. The authors are also grateful for the support from the Organic Health Response–Ekialo Kiona Center's Research Department, staff, and volunteers. This study was published with permission from the Director, KEMRI. The authors also appreciate funding support from the National Science Foundation.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

All authors were involved in the design or implementation of the study and reviewed and approved the final manuscript. EMM and LCHF led the analysis and interpretation with substantive inputs from KJF. BJM and EB provided contributions to the study design and interpretation. EMM, KJF, and BJM were involved in the data collection. EMM wrote the first draft of the manuscript with substantive inputs from KJF and LCHF.

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How to cite this article: Milner EM, Fiorella KJ, Mattah BJ, Bukusi E, Fernald LCH. Timing, intensity, and duration of household food insecurity are associated with early childhood development in Kenya. *Matern Child Nutr*. 2018;14:e12543. https://doi.org/10.1111/mcn.12543