Food Insecurity Affects School Children's Academic Performance, Weight Gain, and Social Skills[1–3]

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ABSTRACT Food insecurity has been associated with diverse developmental consequences for U.S. children primarily from cross-sectional studies. We used longitudinal data to investigate how food insecurity over time related to changes in reading and mathematics test performance, weight and BMI, and social skills in children. Data were from the Early Childhood Longitudinal Study-Kindergarten Cohort, a prospective sample of ~21,000 nationally representative children entering kindergarten in 1998 and followed through 3rd grade. Food insecurity was measured by parent interview using a modification of the USDA module in which households were classified as food insecure if they reported ≥1 affirmative response in the past year. Households were grouped into 4 categories based on the temporal occurrence of food insecurity in kindergarten and 3rd grade. Children's academic performance, height, and weight were assessed directly. Children's social skills were reported by teachers. Analyses examined the effects of modified food insecurity on changes in child outcomes using lagged, dynamic, and difference (i.e., fixed-effects) models and controlling for child and household contextual variables. In lagged models, food insecurity was predictive of poor developmental trajectories in children before controlling for other variables. Food insecurity thus serves as an important marker for identifying children who fare worse in terms of subsequent development. In all models with controls, food insecurity was associated with outcomes, and associations differed by gender. This study provides the strongest empirical evidence to date that food insecurity is linked to specific developmental consequences for children, and that these consequences may be both nutritional and nonnutritional. J. Nutr. 135: 2831–2839, 2005.

KEY WORDS: • *food insecurity* • *child development* • *overweight* • *academic* • *longitudinal*

Despite federal food assistance and private charitable programs, food insecurity is a persistent national problem (1), affecting 11% of all households (2) and 16% of households with children (3). Food insecurity refers to limited or uncertain availability of or inability to acquire nutritionally adequate, safe, and acceptable foods due to financial resource constraint (1). More specifically, food insufficiency refers to an inadequate amount of food intake due to resource constraint (4).

Food insecurity and insufficiency are associated with adverse health and developmental outcomes in U.S. children (5–12). Among 6- to 12-y-old children, food insufficiency was associated with poorer mathematics scores, grade repetition, absenteeism, tardiness, visits to a psychologist, anxiety, aggression, psychosocial dysfunction, and difficulty getting along with other children (13–15). Among 15- to 16-y-old adolescents, food insufficiency was associated with depressive disorders and suicide symptoms after controlling for income and other factors (16). Recently, food insecurity was associated with poor social functioning, but not with academic performance or attained BMI, in kindergarten children (17).

Cross-sectional studies also suggest possible associations between food insecurity and overweight in children. White girls 8–16 y old from food-insufficient households were 3.5 times more likely to be overweight than food-sufficient girls after controlling for potential confounding factors (18). Casey and colleagues (19) reported a significantly higher prevalence of overweight among children from low-income, food-insufficient households in contrast to high-income, food-sufficient households, but no differences between food-insufficient and food-sufficient low-income households.

These cross-sectional studies suggest that food insecurity has consequences for academic performance, social skills, and weight in children. Longitudinal data, however, have clear analytical advantages over cross-sectional data. First, the temporal nature allows for measurement of change over time (20). For example, how does the transition from food security to food insecurity relate to weight gain? Second, temporality helps ensure that observed outcomes are associated with initial

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exposure status and not due to reverse causality. Third, investigation of intraindividual changes reduces the effects of unmeasured confounders (20). Absent a randomized design, longitudinal data provide the best means to establish that observed effects are causal and not due to confounding, selection bias, or reverse causality (21).

Only one earlier study examined the effects of food insecurity on aspects of child development using longitudinal methods (22). Data from the Early Child Longitudinal Study-Kindergarten Cohort (ECLS-K)[5] showed that reporting ≥3 indicators of food insecurity in the spring of kindergarten was not associated with physical growth across the kindergarten year, but that reporting at least 1 indicator of food insecurity was significantly associated with impaired learning in mathematics from fall to spring of the kindergarten year. This study was limited by the short duration of time between assessments, lack of data on changes in food insecurity, and inability to establish whether exposure to food insecurity preceded the learning effect.

This study aimed to determine relations between household food insecurity and selected dimensions of children's academic, social, and physical development over several years using a prospective longitudinal study design and modeling techniques that attempt to account for bias. The selected developmental outcomes were mathematics performance, reading performance, weight, BMI, and composite social skills. First, we examined whether household food insecurity at kindergarten resulted in poorer subsequent development. Second, we examined how changes in food insecurity were associated with concurrent development.

SUBJECTS AND METHODS

Nonrestricted, public-use data were obtained from the ECLS-K (23), which utilized a multistage probability, cluster sample design to select a nationally representative sample of 21,260 kindergarten children attending 1592 elementary schools in 1998–1999. Data were collected nonexperimentally by means of survey and direct assessment over 4 consecutive years. We utilized parent, teacher, and child data from spring of kindergarten (1999) and spring of 3rd grade (2002). Data from children with full response, i.e., eligible children who completed some assessment data *or* had a parent who completed the family section of the parent interview, were available for 20,578 children in the spring of 1999 and for 15,305 children in the spring of 2002. Attrition was due mainly to children moving outside of the primary sampling units or moving to areas in which they could not be located. Locatable movers from a random 50% of schools were followed. A small number of children became ineligible because they moved outside of the United States or died. Our 2 analytic samples consisted of the following: *1)* ~13,500 children for whom full data, i.e., a scored reading or mathematics assessment *and* parent completion of the USDA food security module, were available at kindergarten; and *2)* ~11,400 children for whom these full data were available at both kindergarten *and* 3rd grade.

The ECLS-K longitudinal design offered 4 advantages. First, it gave an opportunity to analyze the effects of changes in food security status over time. Second, the large sample size allowed for substantial statistical power. Third, national representation of the sample allowed for generalizations to the entire population. Fourth, ample supplementary information regarding characteristics of the children, parents, and home environments was collected as part of the ECLS-K.

Food insecurity. Household food insecurity was measured using the USDA's Household Food Security Survey Module, an 18-item scale designed to capture experiences associated with inadequate quality and quantity of the household food supply within the past 12 mo (1,24). The USDA module was administered to parents by means of telephone interviews in the spring of 1999 and the spring of 2002. Parents responded in the affirmative or negative to each of the experiences itemized in the scale. In standard guidelines for use (1), households that affirm ≤2 responses are classified as food secure, and households that affirm ≥3 responses are classified as food insecure.

A previous study using ECLS-K data suggested that experiencing food insecurity at even marginal levels is associated with child development (22). Using the standard threshold of ≥3 affirmative responses to the USDA food security module had less value in predicting mathematical test performance than a threshold of ≥1 affirmative responses on the module. Also, households affirming 1 or 2 responses (labeled marginally food secure) were more similar in mean baseline characteristics to households affirming >2 responses than households affirming no responses. The authors concluded that reporting *any* affirmative response on the module signifies increased food insecurity.

We created 2 separate binary variables to represent the experience of food insecurity in both 1999 and 2002. For the first variable, only households reporting ≥2 affirmative responses on the USDA module were coded as food insecure; all other households were coded as food secure. For the second variable, households reporting *any* (≥1) affirmative response on the USDA module were coded as food insecure; households reporting 0 affirmative responses were coded as food secure. Of the households having valid responses, 8.7% reported ≥3 affirmative responses and 17.1% reported at least 1 affirmative response. Our preliminary results confirmed that the second measure better predicted differences in development, and this variable was used for all successive analysis.

To capture changes in food insecurity over time, a categorical variable was created to represent transitions into and out of food insecurity. Respondents were categorized into 4 groups: remained food secure at both times (persistent food secure), remained food insecure at both times (persistent food insecure), transitioned from food security to food insecurity (became food insecure), and transitioned from food insecurity to food security (became food secure).

Academic performance. Direct assessments of mathematics and reading ability were administered individually in kindergarten and 3rd grade. The mathematical proficiency test measured understanding of the properties of numbers, mathematical operations, problem solving, understanding of patterns and relations among numbers, formulating conjectures, and identifying solutions. The reading proficiency test measured basic literacy, vocabulary, and reading comprehension (24).

Scaled scores for the mathematics and reading performances were calculated using item response theory (IRT). Although assessments are grade-appropriate and nonidentical over time, IRT places each score on a continuous ability scale, making possible longitudinal measurements of gain in achievement. The scores represent estimates of the number of items students would have answered correctly had they completed all of the questions in all of the first- and second-stage forms. Values for IRT mathematics and reading scores ranged from 0 to 123 and from 0 to 154, respectively. Reliability of the test scores was high, between 0.92 and 0.95 (24).

Weight, height, and BMI. Children's heights and weights were assessed directly in both kindergarten and 3rd grade. A Shorr Board was used to obtain height measurements. A digital bathroom scale was used to obtain weight measurements. Heights and weights were each measured twice to minimize measurement error and the mean of each set of values was used. If 2 height values were ≥5 cm apart, the composite height was set as the value closest to 109.2 cm (the mean height for a 5-y-old child) at kindergarten. If the 2 weight values were ≥2.3 kg apart, the composite weight was set as the value closest to 18.2 kg (the mean weight for a 5-y-old child) at kindergarten. BMIs (kg/m^2) were calculated from heights and weights (24). Weights and BMIs were within normal ranges for appropriate ages (25).

Social skills. Children's social skills were assessed by teacher questionnaires. Teachers rated how often their students exhibited certain social skills and behaviors on a scale of 1 (never) to 4 (very often), for a variety of behaviors within each of 5 overall scales. Of the 5 scales, 3 captured positive aspects of children's development:

[5] Abbreviations used: ECLS-K, Early Child Longitudinal Study-Kindergarten Cohort; FIS, food insecurity; IRT, Item Response Theory.

approaches to learning (behaviors that affect ease of benefiting from the learning environment); self control (ability to control behavior); and interpersonal skills (forming and maintaining friendships, getting along despite differences, comforting or helping others, and showing sensitivity). The other 2 scales captured externalizing (acting-out) and internalizing (anxiety, loneliness, low self-esteem, sadness) problem behaviors. Scores were computed only if the student was rated on at least two-thirds of the items within each of the 5 scales. All of these measures were adapted from Gresham and Elliott's (26) Social Skills Rating System. The reliability for the teacher social rating scales was high (24).

After preliminary analysis with individual scales, we averaged the individual scales to create a composite social skills behavior score, in which a higher score indicated better social skills. The scale for internalizing problem behaviors was not averaged into the score for 2 reasons: first, its low correlation with the other scale measures, and second, previous literature questioning the validity of teacher-ratings of internalized behaviors (27–29). Change in social skills score was calculated by subtracting the kindergarten composite score from the 3rd grade composite score. Separate analysis was done using a composite average of all 5 scales (including internalizing behaviors) and yielded similar results.

Control measures. Controlling for many individual, parent, and household variables in the analysis reduced the possibility of spurious associations between the variables of interest. The following child-specific data were collected using direct assessment and parent report at both times: gender, age, birth weight, home language, race-ethnicity, disability (diagnosed activity, mobility, speech, hearing or vision problem), health insurance coverage, and frequency of exercise per week. Children were classified into 4 race-ethnicity categories: non-Hispanic white, non-Hispanic black or African-American, Hispanic of any race, and other (which includes children of Native American and Asian descent). Children were categorized as normal birth weight, low birth weight (≥1500 and <2500 g), or very low birth weight (<1500 g). We created dichotomous variables for the following: non-English as the home language, the presence of a child disability, and child health insurance coverage. Child psychomotor skills were assessed at kindergarten only and rated on a composite scale of 0 (poor) to 17 (excellent).

Parents reported the following information about home environments at both times: family income (multiples of $5000 up to $40,000; $40,001–50,000; $50,001–75,000; $75,001–100,000; $100,001–200,000; >$200,001), number of parents in household (1; 2; no biological/step parents), household size (total number people), mother's age, father's age, parent marital status (married; divorced; widowed; separated; never married; no biological/adoptive parent in home), mother's age at 1st birth, parent employment (≥35 h/w; <35 h/w; looking for work; not in labor force; no mother/father in household), highest education level attained by either parent (<8th grade; 9th-12th; high school diploma; vocational/technical program; some college; bachelor's degree; some graduate/professional school; master's degree; doctorate/professional degree), child care arrangements (no nonparental care; relative care; nonrelative care; center-based program; other/variation), number of siblings, parent ratings of his or her own depression and ability to "get going" (never; sometimes/moderate amount; most of time;), region of residence (Northeast; Midwest; South; West), area of residence (large/mid-size city; suburb/large town; small town/rural), and neighborhood safety rating (not at all safe; somewhat safe; very safe). Data regarding the death of a close relative in the past 2 y and the number of places the child had lived in the past 3 y were collected in the spring of 2002 only.

Composite variables were created to capture transitions between kindergarten and 3rd grade for relevant background variables. Categorical variables were as follows: child disability (no change; became disabled, became nondisabled), child health insurance (no change; became covered, became uninsured), parent marital status (no change; became married, became divorced, became separated, became widowed), parent employment (no change; became part time; became full time; change to looking; change to not in labor force); child care arrangements (no change; change to no nonparental care; started center-based care; started relative care; started nonrelative care), region of residence (no change; moved to Northeast; moved to South; moved to Midwest; moved to Pacific), and area of residence (no change: moved to large city; moved to large town/suburb; moved to rural/small town). Differences between kindergarten and 3rd grade values were computed for the following: child's frequency of exercise, household income, number of parents, household size, highest education level attained by either parent, number of siblings, parent ratings of his or her own depression and ability to "get going," and neighborhood safety rating.

Statistical methods. Preliminary analyses showed nonnormal distributions for change in BMI, change in weight, initial mathematics score, and initial reading score. Logarithmic transformations of these variables were used to create measures with normal distributions. Results for means are reported after back transformations. Results for differences, i.e., β-coefficients, are reported after back transformations using the sample means and differences from the regression coefficients obtained on the logarithmic scale.

Initial analysis determined whether children with missing data due to loss to follow-up differed in any way from those with complete data. A binary variable distinguished children with missing data from those with complete data across both time points, which was then regressed (logistic) upon all available background variables. Any variable identified as predicting the probability of missing data was included in the analysis as a covariate.

Multiple linear regression methods were used to test the differential effects of food insecurity transitions on the 5 child developmental outcomes of interest: change in mathematics score, change in reading score, change in weight and BMI (controlling for height), and change in social skills score. The SAS *surveyreg* (version 9.1, SAS Institute) procedure accounted for effects of survey clustering, primary sampling units, and sample weights. ECLS-K sampling weights adjusted for an oversampling of Asian and Pacific Islanders and nonresponse. Analyses were run using the full sample and gender-stratified samples. Differences were considered significant at the 5% level.

Models. Each of the 5 developmental outcomes was analyzed using 4 models: *1*) lagged model without controls, *2*) lagged model with controls, *3*) dynamic model, and *4*) difference model. The lagged model assessed the effects of initial food insecurity on subsequent development. This model makes use of the temporal sequence to establish that food insecurity precedes its effect and that the association is not likely due to reverse causality. For the first analysis, change in development score was modeled as a function of initial development score and initial food insecurity (food insecure vs. food secure):

$$\Delta\ \text{score}_{3-k} = \beta_0 + \beta_1\ \text{score}_k + \beta_2\ \text{FIS}_k + E$$

where the subscripts 3 and k refer to the time of assessment (3rd grade or kindergarten) and FIS refers to food insecurity status.

The previous model estimated effects of kindergarten food insecurity on subsequent developmental trajectories without regard to background characteristics. A second lagged model was conducted in which time-invariant variables were controlled:

$$\Delta\ \text{score}_{3-k} = \beta_0 + \beta_1\ \text{score}_k + \beta_2\ \text{FIS}_k + \beta_3\ \text{covariates}_k + E$$

To reduce bias further, a third lagged model was conducted in which both time-invariant and time-varying variables were controlled:

$$\Delta\ \text{score}_{3-k} = \beta_0 + \beta_1\ \text{score}_k + \beta_2\ \text{FIS}_k + \beta_3\ \text{covariates}_k + \beta_4\ \Delta\ \text{covariates}_{3-k} + E$$

Although the lagged model is useful in establishing direction, it does not take into account food insecurity at 3rd grade. A dynamic model has the advantage of capturing the differential effects of food insecurity between kindergarten and 3rd grade. For the dynamic model analysis, change in the development score was modeled as a function of the initial development score, time-invariant covariates, time-varying covariates, and food insecurity modeled as a 4-category variable to capture both persistent and transitional effects:

$$\Delta\ \text{score}_{3-k} = \beta_0 + \beta_1\ \text{score}_k + \beta_2\ \Delta\text{FIS}_{3-k} + \beta_3\ \text{time-invariant covariates}_k + \beta_4\ \text{time-varying covariates}_k + \beta_4\ \Delta\ \text{time-varying covariates}_{3-k} + E$$

The difference model is a reduced version of the dynamic model concerned only with transitions. Change in the development score was modeled as a function of time-varying covariates and change in household food insecurity:

$$\Delta \text{ score}_{3-k} = \beta_0 + \beta_1 \Delta \text{FIS}_{3-k} + \beta_2 \Delta \text{ covariates}_{3-k} + E$$

Continuous variables, including food insecurity, were entered into the model as differences. Categorical variables were entered into the class statement, with 0 representing no change from kindergarten to 3rd grade and each level other than 0 representing a change in status (e.g., 1 = became divorced, 2 = became married, 3 = became widowed).

The difference model removes individual fixed effects and eliminates the influence of time-invariant unobserved (and observed) heterogeneity by differencing out effects of factors that remain unchanged over time and focusing entirely on transitions. Theoretically, this model gives the least biased estimates of association (30), assuming that there is a short lag between the experience of becoming food insecure and its effect on child development relative to the duration of time between measurements. We controlled for as many relevant child- and household-level time-varying covariates as available.

RESULTS

Background characteristics for the subset of children with full data are summarized in Supplemental Tables 1 and 2. Included are the characteristics for the 15.6% of kindergarteners from households affirming ≥1 response on the USDA food security module. Supplemental Table 3 summarizes background characteristics over time. Characteristics of the entire sample at kindergarten were reported elsewhere (17). Between kindergarten and 3rd grade, 77.9% of children's households remained food secure, 6.0% remained food insecure, 9.7% became food secure and 6.5% became food insecure (n = 11,460); 22.2% experienced food insecurity at one *or* both times.

Observed changes in outcomes were in the expected ranges for child age and developmental stage **(Table 1)**. Reading IRT score increased by 70.43 points, mathematics IRT score by 53.37 points, weight by 10.96 kg, and BMI by 1.99 kg/m^2. The teacher-rated social skills score changed little (−0.06 points). Weights at kindergarten and 3rd grade were slightly above the expected norm for the U.S. population. The observed mean weight of 22.5 kg and mean age of 6.23 y at kindergarten corresponded roughly to the 65th percentile weight-for-age for the U.S. population. Three years later, the observed mean weight of 34.26 kg corresponded roughly to the 75th percentile weight-for-age for the U.S. population (25).

Without controlling for background variables, the lagged model showed that children from households experiencing food insecurity at kindergarten demonstrated a 2.34-point smaller increase in mathematics score, a 4.39-point smaller increase in reading score, a 0.27-U greater gain in BMI, a 0.44-kg greater gain in weight, and a 0.08-point greater decline in social skills score than children from food-secure households at kindergarten **(Table 2)**. Stratification by gender showed that the associations between academic outcomes and kindergarten food insecurity were significant for both boys and girls. Associations between kindergarten food insecurity and changes in BMI and weight were significant for girls only (β = 0.503 kg/m^2 and β = 0.827 kg). The association between kindergarten food insecurity and change in social skills was significant for boys only (β = −0.135).

After controlling for both time-varying and time-invariant covariates in the lagged model, the association between kindergarten food insecurity and change in mathematics score remained negative, although this was significant only for girls (β = −1.766, $P < 0.017$). Kindergarten food insecurity also had significant effects on BMI, weight, and social skill outcomes among girls only (β = 0.428 kg/m^2, β = 0.764 kg, and β = 0.09 points). Sign changes were observed for reading performance, BMI, and weight outcomes among boys, but these associations were not significant.

Over time, persistent food insecurity as well as transitions into and out of food insecurity were related to several outcomes **(Table 3)**. Children from persistently food *insecure* households had a 0.35 kg/m^2 greater gain in BMI ($P < 0.028$) and a 0.65 kg greater gain in weight ($P < 0.026$) compared with children from persistently *food secure* households after controlling for all time-invariant and time-varying covariates, including initial height and change in height. These associations were significant among girls (β = 0.55 kg/m^2 and β = 1.041 kg, respectively) but not among boys in the stratified analysis.

Persistent food insecurity was not associated with differential changes in mathematics score, reading score, or social skills score when contrasted with persistent food security in the full sample. Among girls only, however, persistent food insecurity was associated with a smaller increase in reading score (β = −2.91; $P < 0.078$)) than persistent food security. Children from households transitioning from food *security* to food *insecurity* exhibited a 3.21 point smaller increase in reading score ($P < 0.0007$) in contrast to children from households remaining food secure. This contrast was significant regardless of gender. Children from households transitioning from food *insecurity* to food *security* exhibited a 1.50 point smaller increase in mathematics score ($P < 0.005$) in contrast to children from households remaining food secure. Transitioning

TABLE 1

Selected developmental outcomes at kindergarten (K) and 3rd grade, and changes in outcomes[1,2]

Outcome	Spring, 1999 K		Spring, 2002 3rd Grade		Difference, K to 3rd Grade	
	n		n		n	
Mathematics score	13,556	32.17 ± 11.57	12,362	85.49 ± 17.75	11,460	53.37 ± 12.35
Reading score	13,055	39.35 ± 13.55	12,287	108.70 ± 20.03	10,990	70.43 ± 16.12
BMI, *kg/m^2*	13,504	16.42 ± 2.32	11,936	18.63 ± 3.86	11,011	1.99 ± 2.12
Weight, *kg*	13,511	22.58 ± 4.45	11,972	34.26 ± 9.19	11,056	10.98 ± 5.08
Social skills score	13,119	3.22 ± 0.55	10,169	3.18 ± 0.56	9261	−0.06 ± 0.54

[1] Values are means ± SD.
[2] Includes children with complete data: scored academic assessment and food security portion of parent interview completed.

TABLE 2

Lagged model effects of kindergarten (K) food insecurity on outcomes[1]

	Controlling only for K outcome		Effect of K food insecurity additionally controlling for K background covariates[2]		Additionally controlling for changes (K–3rd grade) in background covariates[3]	
Outcome, K–3rd grade	*n*	β-Coefficient (*P*-value)	*n*	β-Coefficient (*P*-value)	*n*	β-Coefficient (*P*-value)
Δ Mathematics scaled score						
All	11,180	−2.335 (<0.0001)	9090	−1.303 (0.0116)	8191	−1.474 (0.0051)
Boys	5682	−2.099 (0.0009)	4497	−1.038 (0.1695)	4157	−1.091 (0.1652)
Girls	5498	−2.578 (<0.0001)	4365	−1.589 (0.0176)	4034	−1.766 (0.0165)
Δ Reading scaled score						
All	10,758	−4.387 (<0.0001)	8545	−0.631 (0.3249)	7907	−0.242 (0.7222)
Boys	5452	−3.878 (<0.0001)	4332	−0.545 (0.5120)	4010	0.097 (0.9114)
Girls	5306	−5.116 (<0.0001)	4213	−1.025 (0.2358)	3897	−0.738 (0.4220)
Δ BMI[4] (kg/m^2)						
All	10,869	0.274 (0.0003)	8571	0.088 (0.4184)	7898	0.162 (0.1151)
Boys	5534	0.082 (0.4156)	4360	−0.181 (0.1285)	4013	−0.098 (0.3922)
Girls	5335	0.503 (<0.0001)	4211	0.384 (0.0137)	3885	0.428 (0.0022)
Δ Weight[4] (kg)						
All	10,869	0.440 (0.0036)	8571	0.260 (0.2365)	7898	0.276 (0.1341)
Boys	5534	0.128 (0.4934)	4360	−0.205 (0.3817)	4013	−0.210 (0.3127)
Girls	5335	0.825 (0.0002)	4211	0.740 (0.0155)	3885	0.761 (0.0024)
Δ Social skills scaled score						
All	9160	−0.083 (<0.0001)	7295	0.007 (0.7858)	6812	0.013 (0.5919)
Boys	4595	−0.135 (<0.0001)	3648	−0.052 (0.1464)	3411	−0.048 (0.1743)
Girls	4566	−0.037 (0.1538)	3648	0.083 (0.0054)	3401	0.091 (0.0016)

[1] Food insecurity is defined as ≥1 affirmative response on the USDA Module.
[2] Controlling for kindergarten outcome score, child's age, child's gender, child's race-ethnicity, whether child was low birth weight, initial child disability status, initial child health insurance status, whether first language spoken at home not English, initial household income, initial household size, initial frequency of child's exercise, parents' age, mother's age at first birth, initial parent marital status, initial parent highest education, initial parent depression rating, initial parent rating of ability to get going, initial child care status, initial parent employment status, initial number of parents, initial number of siblings, initial neighborhood safety rating, initial area of residence, and initial region of residence.
[3] Additionally controlling for *changes* in: disability status, child health insurance status, household income, household size, frequency of exercise, parent marital status, parent highest education, parent depression rating, parent rating of ability to get going, child care status, parent employment status, number of parents, number of siblings, region of residence, area of residence, neighborhood safety rating; number of close relatives died in past 2 y, number of residences for >4 mo in past 2 y.
[4] Additionally controlling for child's initial height and change in height.

from food *insecurity* to food *security* was also associated with a greater increase in social skills score for girls ($P < 0.0001$) but with a smaller increase in social skills for boys ($P < 0.038$).

Significant effects of food insecurity were found using the difference model as well (**Table 4**). When children from households that became food *insecure* were contrasted with children from households that became food *secure*, food insecurity was associated with a smaller increase in reading score ($\beta = -3.41$; $P < 0.005$). Although the observed associations were negative for both boys and girls, the association for boys was somewhat weaker and not significant.

Gender-stratified analysis using the difference model showed differential effects of food insecurity on BMI, weight, and social skills. Becoming food insecure was associated significantly with *greater* weight and BMI gains among boys ($\beta = 1.165$ kg and $\beta = 0.430$ kg/m^2, respectively) but nonsignificantly with *smaller* weight and BMI gains among girls ($\beta = -0.809$ kg and $\beta = -0.446$ kg/m^2, respectively). Becoming food insecure was associated with a greater *decline* in social skills score among girls ($\beta = -0.135$; $P < 0.005$) but with greater *improvement* in social skills score among boys ($\beta = 0.124$; $P < 0.050$).

DISCUSSION

The first aim of the study was to examine the effects of household food insecurity at kindergarten on subsequent selected dimensions of child development. Food insecurity at kindergarten predicted impaired academic performance in reading and mathematics for girls and boys, a greater decline in social skills for boys, and greater weight and BMI gains for girls. Food insecurity thus serves as an important marker for identifying children with delayed trajectories of development.

After controlling for known confounders in the lagged model, food insecurity at kindergarten predicted poorer mathematics performance for girls, greater BMI and weight gains for girls, and greater improvement in social skills for girls. The relation between social skills and food insecurity in girls was unexpected. A limitation of using the lagged model, however, is that it does not control for changes in food insecurity between kindergarten and 3rd grade, that is, we do not know whether the improvement in social skills observed among girls was due to initial food insecurity or simultaneous improvements in food security. In fact, the dynamic model showed the greatest improvement in social skills was among girls from households becoming food insecure between kindergarten and 3rd grade.

For the second aim, we examined the relation of changes in food insecurity over time and concurrent development using dynamic and difference models, each having its own advantages. Whether contrasted with children from persistently food-secure households (in the dynamic model) or households that became food secure (in either the dynamic or difference

TABLE 3

Dynamic model effects of food insecurity over time[1,2]

Outcome, K–3rd grade	*n*	Effect over time in comparison to persistently food secure: Persistently food insecure	Became food secure	Became food insecure	Food insecure at any time	In comparison to Became food secure: Became food insecure
		β-Coefficient (P-value)				
Δ Mathematics scaled score						
All	8189	−0.615 (0.462)	−1.503 (0.005)	−0.957 (0.220)	−1.025 (0.032)	0.546 (0.541)
Boys	4155	−0.085 (0.942)	−1.156 (0.147)	0.008 (0.942)	−0.411 (0.543)	1.164 (0.406)
Girls	4034	−1.098 (0.326)	−1.680 (0.045)	−1.451 (0.156)	−1.41 (0.039)	0.114 (0.853)
Δ Reading scaled score						
All	7906	−0.902 (0.421)	0.081 (0.908)	−3.209 (0.0007)	−1.343 (0.039)	−3.290 (0.003)
Boys	4009	1.219 (0.330)	−0.419 (0.688)	−2.834 (0.069)	−0.820 (0.414)	−2.415 (0.168)
Girls	3897	−2.911 (0.078)	0.739 (0.465)	−3.568 (0.0035)	−1.913 (0.030)	−4.307 (0.003)
Δ BMI[3] (kg/m^2)						
All	7896	0.354 (0.028)	0.027 (0.809)	0.018 (0.889)	0.133 (0.151)	−0.009 (0.956)
Boys	4011	0.196 (0.300)	−0.232 (0.076)	0.107 (0.584)	0.024 (0.848)	0.339 (0.119)
Girls	3885	0.552 (0.021)	0.313 (0.060)	−0.075 (0.704)	0.263 (0.052)	−0.388 (0.119)
Δ Weight[3] (kg)						
All	7896	0.649 (0.026)	0.034 (0.869)	0.092 (0.701)	0.258 (0.122)	0.059 (0.840)
Boys	4011	0.319 (0.353)	−0.438 (0.068)	0.243 (0.496)	0.124 (0.854)	0.680 (0.092)
Girls	3885	1.040 (0.016)	0.535 (0.068)	−0.069 (0.841)	0.502 (0.038)	−0.605 (0.165)
Δ Social skills scaled score						
All	6812	0.020 (0.625)	0.008 (0.739)	−0.030 (0.287)	−0.001 (0.982)	−0.039 (0.255)
Boys	3411	0.021 (0.711)	−0.080 (0.038)	−0.009 (0.826)	−0.023 (0.467)	0.071 (0.169)
Girls	3401	0.033 (0.542)	0.123 (<0.0001)	−0.060 (0.101)	0.032 (0.269)	−0.182 (<0.0001)

[1] Food insecurity is defined as ≥1 affirmative response on the USDA Module.
[2] See Table 2, footnotes 2 and 3.
[3] Additionally controlling for child's initial height and change in height.

model), children from households that became food insecure exhibited poorer reading performance, and this was especially significant among girls. The magnitude of the difference was about one-fourth of the SD of the change from K to 3rd grade. For girls, there is evidence for a relatively short lag between food insecurity and its effects on reading from comparing results in Tables 2 and 3. Persistent food insecurity through 3rd grade increased the delay in reading ($\beta = -2.911$) relative to the effect of food insecurity at kindergarten alone ($\beta = -0.738$). The association of kindergarten food insecurity with reading performance was reversed if the household was no longer food insecure by 3rd grade ($\beta = 0.739$). Given evidence of a short lag, and that the difference model theoretically provides the least biased estimates of association under this assumption, we conclude that the difference model represents a true association between food insecurity and delayed reading performance among girls. Although the direction of the association was the same for boys, the association was not significant, and there was no evidence for a relatively short lag.

For predicting mathematics performance, the effect of food insecurity at kindergarten, rather than the change in status over time, mattered most for boys and girls. Coefficients for remaining food insecure or becoming food secure (dynamic model) were similar to the effects of kindergarten food insecurity (lagged model) on mathematics performance, suggesting no effect of 3rd grade status. This may be due in part to the possibility of a long lag between food insecurity and its effect on mathematics performance.

Although the links between malnutrition and cognition (31) and between fasting and cognition in children (32) are well established, the literature reporting on the effects of less severe forms of food insecurity on academic performance is less consistent. Two studies reported significant associations between food insecurity and lower test scores for arithmetic, letter-word, and passage comprehension (7,15), although associations with reading performance and 2 other measures of cognitive functioning were not found to be significant in one of the studies (15). Alternatively, 3 studies reported no significant cross-sectional associations between food insecurity and cognitive or academic performance (8,11,17). No studies to date have attempted longitudinal, gender-stratified analyses; therefore, this study advances the field by providing the strongest longitudinal evidence that food insecurity is associated with impaired reading performance for girls. Our study is also consistent with previous findings using ECLS-K of a negative association between kindergarten food insecurity and mathematics learning (22).

This is the first study to investigate the longitudinal relation between household food insecurity and social skills in children. Comparisons between Tables 2 and 3 suggest a short lag between food insecurity and socials skills for girls: food security status at 3rd grade changes the observed effect on social skills relative to kindergarten food insecurity. Under the assumption of short lag, we find an association between food insecurity and impaired social skills among girls. Girls from households becoming food insecure exhibited smaller gains in social skills whether compared with girls from households becoming food secure ($\beta = -0.135$ in difference model, $P < 0.005$) or persistently food secure households ($\beta = -0.06$ in dynamic model; $P < 0.101$). For boys, unexpectedly, it appears that the transition from food *insecurity* to food *security* is associated with modest deficits in social skills over time ($\beta = -0.124$ in difference model; $P < 0.050$). Evidence for a short lag is less clear for boys, however, making this association questionable.

This study used teacher reports of social skill competence

TABLE 4

Difference model effects of transitions in food insecurity status[1]

Outcome, K–3rd grade	*n*	Became food insecure vs. became food secure[2]
		β-Coefficient (P-value)
Δ Mathematics scaled score		
All	8775	−0.012 (0.991)
Boys	4450	0.168 (0.911)
Girls	4325	−0.047 (0.974)
Δ Reading scaled score		
All	8471	−3.413 (0.005)
Boys	4292	−3.182 (0.102)
Girls	4179	−3.833 (0.014)
Δ BMI[3] (kg/m^2)		
All	8471	−0.005 (0.978)
Boys	4305	0.430 (0.059)
Girls	4167	−0.446 (0.091)
Δ Weight[3] (kg)		
All	8472	0.135 (0.681)
Boys	4305	1.165 (0.019)
Girls	4167	−0.809 (0.105)
Δ Social skills scaled score		
All	7275	−0.001 (0.986)
Boys	3644	0.124 (0.050)
Girls	3631	−0.135 (0.005)

[1] Food insecurity is defined as ≥1 affirmative response on the USDA Module.

[2] Controlling for change in household income, change in child disability status, change in number of parents in household, change in parental marital status, change in mother's employment status, change in father's employment, change in child insurance status, change in parent depression rating, change in parent rating of ability to get going, difference in household size, change in frequency of child's exercise, whether close relative died in past 2 y, change in parent education status, total number places child lived in past 3 y for more than 4 mo, change in child care status, change in area of residence, change in region of residence, change in number of siblings in household, change in neighborhood safety rating.

[3] Additionally controlling for child's change in height.

rather than parent or child report, direct observation, or a combination of methods. Studies suggest that both teacher and parent reports are important for assessing overall social competence of children (33). These teacher reports did not account for factors such as teacher distress or cultural background (27). Nonetheless, reliabilities for the rating scales were found to be high and teacher-reported social skills provide the best means of measuring social competence in the absence of additional data.

The association between household food insecurity and impaired social skills development among girls is consistent with cross-sectional studies reporting significantly greater risks of psychosocial dysfunction and behavioral and attention problems among hungry and at-risk-for-hunger children compared with not-hungry children (13,14), although neither study reported gender-stratified results and both were restricted to analysis of low-income children. The finding among girls is also consistent with cross-sectional studies linking food insecurity with decreased levels of positive behavior (8), decreased levels of teacher-rated "social ability" (17), difficulty getting along with other children (15), and greater levels of social behavior problems (7,10) in children. No previous study exists, however, to corroborate the potential association between food insecurity and *better* social skills among boys, perhaps due to the lack of gender-stratified, longitudinal analyses.

Less clear are the conclusions that can be drawn from an analysis of the effect of food insecurity on weight or BMI. Although results from the difference model support an association between food insecurity and reduced gain in weight among girls, caution is warranted in interpreting the results due to the possibility of a long lag between cause and effect. Rather, the strong association between kindergarten food insecurity and subsequent greater weight gain among girls remained significant regardless of food insecurity at 3rd grade, suggesting that the change in food security status has little effect. The difference model also suggests an association between food insecurity and *greater* weight gain among boys. From the dynamic model, boys in households that transitioned from food *insecurity* to food *security* gained less weight than boys remaining food insecure, boys remaining food secure, or boys becoming food insecure. Therefore, the association in boys seems to be with change in food security status, giving evidence for a relatively short lag between cause and effect. Unless we are sure about this assumption, however, we do not know whether the difference model provides the least biased estimates of association. This study was not able to control for parental height and weight in assessing effects on child weight and BMI.

Overweight and obesity have emerged in recent years as major public health problems. To date, only one study has looked at the effects of household food insufficiency on child weight status by gender (15). Food insufficiency was associated with a reduced risk of overweight among 2- to 7-y-old girls but with increased risk of overweight among 8- to 16-y-old non-Hispanic white girls. The strong association between kindergarten food insecurity and greater subsequent weight gain among girls in this study could explain the greater risk of overweight among older girls if the effect is cumulative. Two previous cross-sectional studies using ECLS-K to examine effects of food insecurity found no associations with BMI or weight status (17,22)

Several mechanisms may explain the associations between food insecurity and developmental outcomes. One possible mechanism is that food insecurity results in compromised dietary quality or quantity (34). Studies have shown that adults in food-insecure households had lower consumption of fruits and vegetables (35), had less food on hand (35), obtained a higher percentage of energy from carbohydrate (36), and had lower intakes of dietary fiber and other vital nutrients (36) compared with food-secure households. Alternatively, economic deprivation may be associated with consumption of cheap, energy-dense foods that contribute to weight gain (37,38). Either decreases in diet quality or increases in energy density could lead to accelerated weight gain and may relate to academic and social development in children.

Another possible mechanism is that food insecurity acts as a psychological or emotional stressor, affecting parent and child behavior. Lupien and colleagues (39) found that children of low socioeconomic status have significantly higher cortisol levels than children of high socioeconomic status, and that this effect emerges as early as age 6 y. Cumulative exposure to high levels of cortisol in humans has been related to depression, cognitive deficits, and atrophy of brain structures involved in learning and memory (40,41). Several studies showed that economic hardship is linked to increases in children's social behavior problems, and that this association can be mediated by parent-child interactions (40–44) as well as children's feeling of control or mastery over time in relation to perceived financial difficulties (45,46). One study in Canada linked food insecurity directly with stress, anxiety, sociofamilial perturbations, and disrupted household dynamics (47).

The latter mechanism, in which food insecurity acts as a stressor, would better support observed gender differences in the effects of food insecurity. That is, it better explains how food insecurity at the household level could affect girls and boys differentially at the individual level. Previous studies reported gender differences in children's and adolescents' reactions to life stress and acute stress (16,45,47–53). A recent study suggests that higher levels of anxiety may protect preadolescent boys from engaging in antisocial behaviors, which might partially explain the increase in social skills score observed among boys transitioning into food insecurity in this study (53).

Overall, this study provides the strongest empirical evidence to date that food insecurity is linked to developmental consequences for girls and boys, particularly impaired social skills development and reading performance for girls. There are 3 possible explanations for the associations between food insecurity and development outcomes: first, child development problems result in concurrent household food insecurity; second, food insecurity results in concurrent developmental consequences; and third, other variables confound the relation. Because there is no theoretical reason to assume that impaired child development causes household food insecurity and we controlled for confounders at the individual and household levels, the most plausible interpretation of the results is that food insecurity in the early elementary years has developmental consequences. Furthermore, these consequences may be both nutritional and nonnutritional.

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