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Food Insecurity Influences Weight Trajectory in Children with Obesity

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Abstract

Background: Social disadvantage is associated with children's risk of being overweight or obese, but little is known about how it impacts weight trajectory. This longitudinal analysis examines food insecurity and weight change over time among low-income children in a multidisciplinary weight management clinic.

Methods: Food insecurity was assessed between 2008 and 2016 among 794 low-income patients (household income <$60k/year) who attended 3234 visits. Mixed-effects growth curve modeling was used to examine the association between baseline food security status and weight trajectory, using percentage of the 95th percentile for BMI (%BMIp95). Random effects (each child's growth curve) and fixed effects (food insecurity, starting age and %BMIp95, demographics, and months since the initial visit) were modeled, and interactions between food insecurity and elapsed time estimated the influence of food insecurity on weight trajectory.

Results: Mean %BMIp95 was 129% (SD 24%), corresponding to severe obesity. Thirty percent of patients were food-insecure at baseline. After adjusting for other factors, monthly change in %BMIp95 was significantly smaller for food-insecure children compared to food-secure peers (difference in the coefficients for slope: 0.13, SE 0.05, $p = 0.009$). The modeled 12-month change in %BMIp95 was significant for food-secure children (–2.28, SE 0.76, $p = 0.0026$), but not for food-insecure children (–1.54, SE 1.22, $p = 0.21$).

Conclusion: Household food insecurity was associated with a less optimal weight trajectory among children with obesity.

Keywords: clinical management; food insecurity; longitudinal; severe obesity

Introduction

Food insecurity is a social determinant of health that affects many low-income families in the United States.[1] It is defined as ''having inadequate access to sufficient, safe, and nutritious food to meet dietary needs and food preferences for an active and healthy lifestyle.''[2] In 2020, 14.8% of US households with children were food-insecure,[3] and prevalence among individuals in clinical settings (*e.g.*, safety net clinics) was generally higher than the national estimate.[4,5] Having insecure access to food leads to hard choices and trade-offs, such as relying on foods that tend to be energy-dense but with low nutritional value[6] instead of nutrient-dense fruits and vegetables that have a higher cost ''per calorie.''[7] Adults[8] and adolescents[9] with food insecurity have lower diet quality than their food-secure peers. However, there is some evidence that adults may ''shield'' the youngest children in the household from the negative impact of food insecurity on diet quality.[9,10]

In the modern era, the observation of low-income individuals with simultaneous food insecurity (historically a condition of undernutrition) and obesity (a condition of overnutrition) has provoked investigation into the relationship between food insecurity and obesity.[11] However, while studies of adults suggest that food insecurity is

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associated with obesity, particularly among women,[12,13] studies among children have yielded mixed results.[14] Some have suggested that food insecurity is associated with a higher degree of obesity,[9,15–19] some show no association,[20–26] and, yet, others have suggested that there is an inverse relationship.[27–30] Notably, all but one of the published longitudinal analyses have been based on data from the Early Childhood Longitudinal Study (ECLS), which included a wide range socioeconomic status. In the ECLS, less than 9% of children were food-insecure at baseline, and only 1.2% were persistently food-insecure from kindergarten through eighth grade.[31]

Because of the challenges inherent to potential confounding between food insecurity and income, there is value in examining the relationship between food insecurity and obesity in a more uniformly low-income population. One study examined children participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), comparing their food security status in infancy and at their last WIC visit in childhood, where 17% of children were obese. In this study, 24.1% of the sample was food-insecure in infancy, and persistent food insecurity was associated with a 22% greater odds of having obesity as a 2- to 5–year-old.[18] We are unaware of comparable longitudinal analyses evaluating food insecurity that examine older children. Also, with the exception of a single cross-sectional analysis,[19] we are unaware of any clinic-based studies focused on children with obesity.

This analysis addresses an important gap in the literature regarding the influence of food insecurity on weight trajectory in low-income children who already had obesity. Due to the negative influence of food insecurity on dietary intake, it is plausible to hypothesize that families of children with obesity might experience disproportionate challenges to making recommended changes in diet that could lead to improved weight balance, compared to peers who are equally disadvantaged but have more secure access to food. This analysis sought to explore this hypothesis using longitudinal data from children seen in a pediatric obesity clinic where household food insecurity had been assessed upon clinic intake as a social determinant of health.

Objective

Examine whether food insecurity independently influenced weight trajectory in a clinical population of low-income children 2 to 19 years seeking treatment for overweight and obesity.

Methods

Study Setting

The patient population consisted of patients who presented to the pediatric weight management clinic at the Children's Hospital and Research Center from November 2008 to November 2016, with follow-up until closure of that clinic in May 2017. The Healthy Eating Active Living Clinic (called Healthy Hearts between 2008 and 2013) was a multidisciplinary program designed to treat childhood obesity and related illnesses. During an initial 1-hour visit, the child or adolescent and their parent/caretaker met a physician or pediatric nurse practitioner to obtain a comprehensive medical history, review of laboratory tests, and physical examination. The following visits were scheduled with team specialists (dietitian, exercise specialist, or psychologist) along with a physician or pediatric nurse practitioner. Staff offered culturally sensitive, individualized family plans and community referrals to support and sustain healthy lifestyle changes.

The team worked with specialists (*e.g.*, endocrinology) to coordinate medical management for obesity-related diseases such as diabetes, hypertension, and fatty liver disease.

Study Population

Patients at least 24 months of age at the time of their first clinic visit with a starting BMI at or above the 85th percentile (BMI z-score ≥1.04) were included in this analysis. While food insecurity is largely a condition of poverty, low-income individuals can be food-secure due to factors such as resourceful cooking skills and the social safety net. However, the converse is rarely true, and high-income individuals are generally not food-insecure. The analysis was thus limited to children from households whose self-reported income was $60,000/year or less.

Parental informed consent for participation in the clinic database was obtained from parents at the time of entry to the clinical program, as per a protocol approved by the Institutional Review Board at Children's Hospital & Research Center Oakland. Visits were conducted at four sites in Northern California—Oakland, Walnut Creek, Larkspur, and Fairfield, California.

Measures

Anthropometric measurements. At the time of their clinic appointments, body weight and height were measured to the nearest 0.1 kg and 0.1 cm by clinic staff using a digital electronic scale and a wall-mounted stadiometer. The BMI z-score and the percentage of the 95th percentile for BMI, or %BMIp95, were calculated using SAS codes provided by the CDC.[32] The age- and sex-specific %BMIp95 is the threshold above which a child is considered to have obesity, and %BMIp95 quantifies BMI in relationship to this threshold.

A child with overweight (*e.g.*, BMI greater than 85th percentile but below 95th percentile) would have a %BMIp95 below 100%, and a child whose BMI is at the 95th percentile would have a %BMIp95 of exactly 100%. A %BMIp95 of 120% corresponds to severe obesity, and %BMIp95 at or above 140% indicates the highest degree of severe obesity, corresponding to an adult BMI at or above 40.0 kg/m^2. The %BMIp95 is a preferred measurement for children with severe obesity due to increased stability of estimates.[33]

Demographic characteristics. At the intake visit, caregivers were asked a series of self-reported demographic questions. Based on responses for race/ethnicity (respondents asked to ''check all'' that apply), we classified race/ethnicity into five nonoverlapping categories: non-Hispanic white, African American, Asian/Pacific Islander, Hispanic, and Mixed/Other race. This latter category included participants reporting multiple racial/ethnic identities. Participants were categorized by self-reported annual household income (<15,000, 15,000–29,999, 30,000–44,999, or 45,000–60,000). For the purposes of conducting a sensitivity analysis, we also used federal poverty level (FPL) guidelines from 2012,[34] roughly the midpoint of the study period, to create an estimate whether households 200% of the FPL based on reported household income category and household size.

A household was estimated to be at or below 200% of poverty level if household income was at or below $30,000 regardless of the child's household size, if $30,001–$45,000 but household size was three or more, and if income was $45,001–$60,000 if household size was five or more people.

Food security measurement. Household food security was assessed using a 6-item USDA questionnaire[35] that is a reliable substitute for the full USDA Core Food Security Module.[2] Food insecurity is defined as having two or more affirmative answers from a set of six questions that are taken from the core module, including ''The food (I/we) bought just didn't last, and (I/we) didn't have money to get more'' and ''In the last 12 months, did (you/you or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food?''

Statistical Analyses

The *t*-test or the chi-square test was used for the descriptive statistics. To compare the trajectory of the change in outcome (%BMIp95) by food security status, we performed unadjusted and adjusted models. For the unadjusted analysis, we used a polynomial regression model of repeated measures to fit the change in %BMIp95 over time (months from the first visit) for food secure and insecure groups, modeling the slope of linear (months) and quadratic (months^2) terms. The interaction term of food security status with elapsed time (months from the first visit) was used without adjusting for any covariates.

For the adjusted analysis, we used a mixed model growth curve that included food security status, elapsed time since the first visit (months), and interaction terms for food security $\times$ elapsed time (months, months^2) with adjustment for starting value of %BMIp95, starting age category, sex, race/ethnicity, and income. We fitted linear and quadratic terms for months for the growth curves and tested them for the significance of differences between groups. The final model did not add the higher degree polynomial terms because the quadratic term was nonsignificant.

To be able to compare results to available published data in children with comparable severe obesity, we also estimated the changes in %BMIp95 at 12 months.[36] The estimates of the outcome changes at 12 months for food secure and insecure groups were derived from the growth curves.

We also did two sensitivity analyses. The first was to add the total number of visits as an additional covariate in the multivariable growth curve model analysis. Total number of visits was categorized into the following six categories for balance (1, 2, 3, 4–5, 6–8, and 9+ visits). This was done because while the primary analysis evaluates trajectory based on elapsed time (months since first visit), patients did not uniformly have the same number of visits (and thus, exposure to clinical care). The second sensitivity analysis was with the subset of participants in the dataset who had available data regarding household size, enabling estimation of poverty level. This sensitivity analysis added the three-way interaction term of 200% FPL with group $\times$ months slope and quadratic term to examine whether the differences in the growth curves between food secure and insecure groups varied by 200% FPL status.

All analyses were conducted using SAS®, version 9.4 (SAS Institute, Inc., Cary, NC).

Results

Baseline Demographic Characteristics

Mean starting age was 132 (SD 44) months (11 years) and ranged from 27 months (2 years) to 232 months (19 years) (Table 1). The mean BMI z-score was 2.3 (SD 0.6) and the mean %BMIp95 was 129% (SD 24), indicating that this was largely a population with severe obesity. (Only 6.6% of participants had a starting %BMIp95 below 100%). A third (30.6%) of the sample was food-insecure with significant racial/ethnic group. Starting %BMIp95 was higher for food-insecure children (133%, SD 26) compared to food-secure peers (127%, SD 22), $p < 0.01$. Over two thirds (68%) of the patients were Hispanic.

Characteristics of Follow-Up Data

The mean (SD) and median (interquartile) of visits were 4 (3) and 3 (2, 5), respectively. A quarter of patients (23.6%) had a single visit and did not return, 19.8% had two visits, 13.6% had three visits, 18.3% had four to five visits, 13.9% had six to eight visits, and 11% had nine or more visits (highest number of visits had by any single patient was 21). Children with a single visit (187/794) were included in the overall sample but not in the model estimates. Notably, these who had only one visit (187/794) were no more likely than those with follow-up visits (607/794) to be food-insecure ($p = 0.71$), and furthermore did not differ with respect to children with follow-up visits with respect to sex ($p = 0.93$), race/ethnicity ($p = 0.23$), income ($p = 0.72$), or insurance status ($p = 0.75$) (results not shown).

Trajectory of %BMIp95

Food-insecure patients compared to food-secure peers. The slopes for change in %BMIp95 differed significantly between food-secure and insecure groups in

Table 1. Sociodemographic Characteristics of the Sample ($N = 794$)				
	Overall	**Food insecure**	**Food secure**	
Characteristic	**($N = 794$)**	**($n = 243$)**	**($n = 551$)**	***p***
Starting age months	132 ± 44	131 ± 41	132 ± 44	0.64
Starting age category, years, *n* (%)				0.36
2–5	53 (6.7)	13 (5.4)	40 (7.3)	
6–9	167 (21.0)	57 (23.5)	110 (20.0)	
10–13	348 (43.8)	111 (45.7)	237 (43.0)	
14+	226 (28.5)	62 (25.5)	164 (29.8)	
Female, *n* (%)	394 (49.6)	118 (48.6)	276 (50.1)	0.69
Race/ethnicity, *n* (%)[a]				0.01
Non-Hispanic White	46 (5.8)	7 (2.9)	39 (7.1)	
African American	108 (13.7)	37 (15.2)	71 (13.0)	
Asian/Pacific Islander	39 (4.9)	5 (2.1)	34 (6.2)	
Hispanic	540 (68.3)	172 (70.8)	368 (67.2)	
Mixed race	58 (7.3)	22 (9.1)	36 (6.6)	
Annual family income, *n* (%)				0.001
0–$15,000	278 (35.0)	109 (44.9)	169 (30.7)	
$15,001–$30,000	268 (33.8)	72 (29.6)	196 (35.6)	
$30,001–$45,000	142 (17.9)	39 (16.1)	103 (18.7)	
$45,001–$60,000	106 (13.4)	23 (9.5)	83 (15.1)	
<200% FPL[b]	677 (95.2)	212 (96.8)	465 (94.5)	0.19
Starting BMI Z score	2.3 ± 0.6	2.4 ± 0.5	2.3 ± 0.6	0.051
Starting % BMIp95	129 ± 24	133 ± 26	127 ± 22	<0.001
Total no. of visits				0.34
1	187 (23.6)	55 (22.6)	132 (24.0)	
2	157 (19.8)	43 (17.7)	114 (20.7)	
3	108 (13.6)	39 (16.1)	69 (12.5)	
4–5	145 (18.3)	39 (16.1)	106 (19.2)	
6–8	110 (13.9)	41 (16.9)	69 (12.5)	
9+	87 (11.0)	26 (10.7)	61 (11.1)	

[a]Race/ethnicity data were available for $n = 791$ participants, of which 243 and 548 were food-insecure food-secure, respectively.

[b]FPL estimation, calculated using self-reported income level and household size, was available for 711 participants, of which 219 and 492 were food-insecure and food-secure, respectively.

FPL, federal poverty level.

unadjusted and adjusted models. Quadratic terms also differed between food-secure and food-insecure groups in the unadjusted model, but did not remain significant after adjustment for covariates.

Unadjusted analysis of the slope of change in the growth curve of %BMIp95 showed that compared to food-secure peers, children who were food-insecure had less reduction (and thus, less improvement) in their BMI growth curve over time [difference in the linear coefficients of slope (SE): 0.097 (0.043), $p = 0.03$]. Adjusting for other covariates (*e.g.*, starting the value of outcome, starting age, sex, race/ethnicity, and income category), the more modest reduction in slope seen in food-insecure children compared to their food-secure peers remained significant [difference in coefficients of slope (SE): 0.13 (0.05), $p = 0.009$]. This means that compared to their equally low-income peers (all

<$60 k/year household income) who were food-secure, children who were food-insecure had relatively less reduction in their %BMIp95 trajectory over time.

Other covariates in the adjusted model. Having a greater starting BMI was associated with greater decrease (more improvement) in %BMIp95 over time. In contrast, younger starting age was significantly associated with less improvement over time. Compared to older children (14+ years), children aged 2–5 had less reduction in %BMIp95 over time [difference in coefficients of slope (SE): 1.89 (0.39), $p < 0.001$]. Compared to non-Hispanic white children, African American children had less reduction (less improvement) in %BMIp95 over time %BMIp95 [difference in the coefficients of slope: 1.58 (0.45), $p < 0.001$]. Sex did not have a significant association with the %BMIp95 trajectory (Table 2).

Change in %BMIp95 at 12 months. For food-secure children, holding all covariates at their reference values, there was a significant decrease in %BMIp95 (–2.28, SE 0.76, $p = 0.0026$). However, for food-insecure children, the magnitude of change at 12 months was smaller and not significant (−1.54, SE 1.22, $p = 0.21$).

Sensitivity Analysis

There was a comparable number of visits between the food-secure and food-insecure groups. When the model included further adjustment for the number of visits, the main findings remained the same. The three-way interaction terms of 200% FPL status with food security group × slope and quadratic term of the months from the first visit were not statistically significant, indicating that the different growth curves between food security status did not differ by 200% FPL status (results not shown).

Discussion

This analysis is the first to examine the influence of food insecurity on weight status trajectory among children with obesity. It demonstrates the independent influence of this critical social determinant among low-income children, highlighting the challenge that food insecurity presents in weight management. This finding is relevant to clinicians making lifestyle management recommendations to their patients as well as to policy makers looking to support vulnerable children at risk of obesity-related health complications.

To contextualize these findings, change in weight status can be compared to that reported by the Pediatric Obesity Weight Evaluation Registry, which is a database that includes data from children (2–18 years) seen in multidisciplinary pediatric obesity programs across the country, including the clinic in this analysis.[37] Data from 6454 children (median %BMIp95 of 132%) reported that overall, the median change in %BMIp95 at 10–12 months of follow-up (the longest interval reported) was –2.86 (IQR, –8.7 to 1.9).[36] Our analyses of children with comparable weight status who were all low-income showed a comparable significant decrease in %BMIp95 at 12 months (–2.28), but the change seen among the food-insecure children was smaller in magnitude (−1.54) and also not significant. This highlights the disparity; low-income patients with food insecurity compared to their food-secure peers are less successful with improving their weight status.

Table 2. The Coefficient (Standard Error) from the Mixed Model Growth Curves Fitting for the Outcome Variable % BMI Relative to the 95th Percentile ($n = 794$)

	Unadjusted model[a]		Adjusted model[b]	
Variable	**Coefficient (SE)**	***p***	**Coefficient (SE)**	***p***
Months from the first visit				
Slope				
Food-insecure group	–0.008 (0.038)	0.83	–0.062 (0.045)	0.16
Food-insecure vs. food secure group	0.097 (0.043)	0.03	0.134 (0.051)	0.009
Quadratic term				
Food-insecure group	–0.0007 (0.0009)	0.45	0.006 (0.009)	0.53
Food-insecure vs. food secure group	–0.002 (0.001)	0.02	–0.0009 (0.011)	0.93

[a]Mixed model with repeated measures included the fixed effects of the slope and quadratic term of the months from the first visit and their interactions with food security status accounting for the repeated measures for each individual.

[b]Mixed model with the fixed effects of the slope and quadratic term of the months from the first visit and their interactions with food security status adjusting for covariates (starting value of %BMIp95, starting age category, sex, race/ethnicity, and income) and the baseline value of the outcome. The random effects included the intercept, slope, and quadratic terms of the months from the first visit and their interactions with food security status.

%BMIp95, 95th percentile for BMI.

Since 2015, the American Academy of Pediatrics has supported the importance of promoting food security for all children,[38] and there is growing interest in screening for household food insecurity in clinical settings. The 2-item Hunger Vital Sign[4] is a screening tool with sufficient reliability that is feasibly used in a clinical setting.[39,40] Interventions include referral to federal programs (*e.g.*, Supplemental Nutrition Assistance Program) as well as local resources (*e.g.*, food banks and pantries).[41–43] A recent systematic review ($n=23$ studies) documented that in addition to these referrals, some clinic-based programs give vouchers for food and medically tailored meals.[41] The literature includes examinations of the impact on these food-based interventions on health outcomes in adults with chronic disease,[44,45] but comparable studies in children have not been done.

There has been a concern that the ongoing COVID-19 pandemic could plausibly amplify the rate of food insecurity among low-income populations. Initial projections estimated that 34.5% of households with children were food-insecure, suggesting that the rate of food insecurity among families had already tripled in the early months of the pandemic.[46] Many food-insecure children depend on food provided by free and reduced price lunch meal programs, and school closures disrupted that distribution, making these children even more vulnerable.[47,48] The crisis of unemployment evoked by the pandemic also disproportionately impacted poor and working-class families.[49,50] Nationally representative data have since shown that rates were not ultimately as dramatically elevated as initially estimated.[3] More research would be needed to determine the contributing factors which may have blunted this predicted impact.

There are limitations with this study. Because this is an observational analysis of clinical data from a treatment-seeking population, and not a controlled trial, there is a wide range across participants with respect to the number of follow-up visits as well as the time intervals between these follow-up visits. These variations in follow-up number and intervals are accounted for as elapsed time in the mixed model approach, but are nonetheless a limitation. These findings are from a sample of children with severe obesity, and it is therefore difficult to generalize findings to children with normal weight status (and potentially also to children who are ''only'' overweight and not obese).

Furthermore, it was a limitation that food insecurity was not measured at subsequent visits would have been ideal to assess the role of persistent food insecurity. Finally, while detailed data were collected on weight status, there was no data available on dietary intake to quantify diet quality, limiting our ability to examine the hypothesized role of diet quality over time in individuals engaged in treatment for obesity.

Conclusions

This analysis evaluates the independent influence of food insecurity on the trajectory of weight status (measured as %BMIp95) among low-income children seen in a pediatric weight management program over an 8-year period. The growth curves of food-insecure individuals (compared to their food-secure peers) had less decrease in weight status over time compared to food-secure peers. Notably, while food-secure children in this low-income sample significantly decreased their %BMIp95 (at 12 months) to a degree comparable to that seen in other similar pediatric weight management programs, those with food insecurity did not have the same improvement. It may be that families of children with obesity experience disproportionate challenges to making recommended dietary changes that could lead to improved weight balance, compared to peers who are equally disadvantaged but have more secure access to food.

More research is needed to more fully understand the relationship between food insecurity, lifestyle modification, and pediatric weight status trajectory.

Authors' Contributions

J.M.T. conceptualized and designed the study, coordinated and supervised data collection, contributed to data analysis and interpretation of data, drafted the initial article, and reviewed and revised the article. L.X. carried out the data analysis and reviewed and revised the article. L.T.-D. and L.J. collected data and reviewed and revised the article. L.G.R. contributed to data analysis and interpretation of data and reviewed and revised the article. All authors approved the final article as submitted and agreed to be accountable for all aspects of the work.

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