Changes in household food insecurity are related to changes in BMI and diet
quality among Michigan Head Start preschoolers in a sex-specific manner

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ABSTRACT

Children living in households that have recently become food insecure may be particularly vulnerable to adverse weight and dietary changes, but longitudinal studies examining these associations are lacking. Using data from 501 Head Start preschoolers from Michigan (48% male) who were followed during one school year as a part of a randomized obesity prevention trial, we examined changes in children's adiposity indices and dietary quality according to changes in household food insecurity. Household food insecurity change status was categorized as persistently food secure, became food secure, persistently food insecure, or became food insecure. Linear mixed effects models were used to estimate relative changes in BMI-for-age z scores (BAZ), triceps skinfolds-for-age z scores (TAZ), or diet quality (assessed with the 2010 Healthy Eating Index) over the school year according to food insecurity category. We found that girls from households that became food insecure over the year had a 0.21 unit higher gain in BAZ than girls from households that were persistently food secure, after adjustment for potential confounders (95% CI 0.02 to 0.39, $P=0.03$). Girls from households that became food secure had improvements in dietary quality over the year compared to girls from persistently food insecure households (adjusted difference in Healthy Eating Index score change=9.1 points; 95% CI 3.0 to 15.0; $p=0.003$). There were no statistically significant associations with changes in TAZ. Among boys, there were no associations between changes in household food insecurity and changes in BAZ, TAZ, or dietary quality. In summary, we found that BMI and diet quality changes of Head Start preschool girls were correlated with short-term changes in household food insecurity. Continued research efforts should focus on identifying the most effective ways to promote the health of children in food insecure households, especially those who may have recently transitioned or are transitioning into food insecurity.

- 47 **KEYWORDS:** food insecurity; transitions; BMI; adiposity; dietary quality; preschoolers; Head
- 48 Start

INTRODUCTION

Food insecurity affects a substantial proportion of households in the US; in 2014, it was estimated that 19.2% of US households with children were food insecure (Coleman-Jensen et al., 2015). Although household food insecurity has been related to adverse outcomes among the children in the household including behavioral problems (Whitaker et al., 2006), academic performance and psychosocial outcomes (Alaimo et al., 2001a) and health status (Alaimo et al., 2001b; Ryu & Bartfeld, 2012), it is less clear whether household food insecurity is associated with weight gain and dietary quality of the children. This link is plausible, given that children from food insecure households may have greater access to inexpensive, highly processed and calorie-dense food (Drewnowski & Specter, 2004) and/or tend to overeat when food becomes available (Scheier, 2005). Although a few studies have reported that food insecurity in the household was related to higher body mass index (BMI) (Dubois et al., 2006; Willis & Fitzpatrick, 2016), higher gains in BMI (Burke et al., 2016) or lower dietary quality among the children (Kaiser et al., 2002), others have found no association (Gundersen et al., 2009; Hanson & Connor, 2014; Rossen & Kobernik, 2016; Speirs & Fiese, 2016; Trapp et al., 2015). A lack of association has been explained by parents shielding their children from dietary insufficiencies by limiting the quality and/or quantity of their own consumption rather than the children's (Hanson & Connor, 2014). Nonetheless, other research suggests that even when parents think they are effectively shielding children in the household, the children are often aware of the situation and, as a result, may be modifying their dietary behavior (Fram et al., 2011).

Very few studies have examined how changes in food insecurity might be related to concurrent changes in weight and diet. It is salient from a public health perspective to understand whether changes in food insecurity are related to weight and diet changes in this age group.

Rapid weight gain before the age of 5 y has been related to a higher risk of being overweight as a young adult (Sutharsan et al., 2015). One factor of rapid weight gain during childhood could be changes in household food security. During transitions from food security into food insecurity, children in the household may overeat or parents overfeed them in anticipation of a shortage of food. This notion was recently termed the “insurance hypothesis”(Nettle et al., 2016). Study authors theorize that a looming threat of food scarcity causes people to store excess fat in preparation, analogous to behaviors observed in some animals. However, no epidemiological studies have examined whether changes in food insecurity are related to dietary changes. In addition, the few epidemiological studies that have examined whether changes in food insecurity are related to changes in BMI or weight have mixed findings. One study among US women did not find any association between change in food insecurity and BMI (Jones & Frongillo, 2007), whereas one other US study among preschoolers found an association (Jyoti et al., 2005). In the latter nationally representative study, boys from households that became food insecure over a four-year follow-up had a 1.2 kg greater weight gain than households that became food secure over the same time period.

The Growing Healthy study was a randomized controlled trial of an obesity intervention program among low socioeconomic status (SES) Head Start preschoolers from Michigan (Miller et al., 2012). At the beginning and end of one school year, information on household food insecurity, child diet and anthropometry were obtained. This provided us with the opportunity to examine whether changes in food insecurity were related to changes in diet quality and adiposity over the same period. Our primary aim was to ascertain whether children from households that became food insecure over the year had increases in BMI and triceps skinfold thicknesses and declines in dietary quality relative to the BMI, triceps skinfold thicknesses, and dietary quality

changes of children whose households remained food secure. Our secondary aims were two-fold: first, to examine whether children from persistently food insecure households had increases in BMI and triceps skinfold thicknesses and adverse dietary quality changes compared to those from persistently food secure households. However, we did not expect the differences between persistently food secure households and persistently food insecure households to be as large as the difference between households that became food insecure and persistently food secure households. Second, we hypothesized that children from households that became food secure would have losses in BMI and triceps skinfold thicknesses and positive changes in dietary quality scores relative to those from persistently food insecure households.

This study strives to shed light on how low SES preschool children are affected by relatively short-term changes in household food insecurity status. Findings from our study could be interpreted using the theoretical framework of family resiliency, which promotes strengthening family support, belief, and communication systems during times of crises to improve long-term health and well-being of family members (Walsh, 2015). In addition, finding that changes in household food insecurity are related to adverse changes in adiposity and/or diet quality would inform policy aimed at diminishing food insecurity in the US. Therefore, results could be particularly relevant for teachers or public health practitioners who work with Head Start populations while also providing additional evidence for policy makers regarding the impacts of food insecurity on US preschoolers from low SES households.

METHODS

Study Population

The present study was a secondary data analysis of the Growing Healthy Study, a cluster-randomized community-based obesity intervention trial among 697 preschoolers in Head Start programs in urban and rural Michigan from 2011-2015. The study is described in detail elsewhere (Miller et al., 2012). Briefly, children in 18 classrooms per year were randomized to one of three study arms. Parents were invited to participate and received up to \$150 for data collection activities. One arm consisted of exposure to the Preschool Obesity Prevention Series (POPS), a Social Cognitive Theory-based approach to obesity prevention. The second arm included POPS exposure in addition to the Incredible Years Series, a program that emphasizes positive behavioral management techniques (Webster-Stratton & Reid, 2010). The control arm consisted of usual Head Start exposure. Exclusion criteria included the child having significant developmental disability, the child being in foster care, or the caregiver not fluent in English. Informed consent was obtained, and the study was approved by the Institutional Review Boards of the University of Michigan and Michigan State University.

Data Collection

Food Insecurity Measures

Children were assessed once from early September to mid-November and once from late March to mid-May (average length between visits was 6 months). During these in-home visits, primary caregivers provided household and demographic information to a trained interviewer. Household food insecurity was assessed with the US Household Food Security Survey Module, an 18-item questionnaire that inquires about perceived financial difficulties with obtaining an appropriate quantity and quality of food for adults and children during the previous 12 months

(Bickel et al., 2015). In accordance with the Household Food Security Survey Module's recommended cutoffs, a household was considered food insecure if there was an affirmative response to 3 or more questions. This corresponds to "low food insecurity", meaning that there are concerns about the adequacy of the food supply or adjustments to food management, but not necessarily reductions in absolute food intake.

Anthropometric Measurements

Trained research assistants measured height (in meters (m)) and weight (in kilograms (kg)) of children and caregivers during home visits using calibrated equipment (Seca 213/217 portable stadiometer and Detecto Portable Scale Model #DR550C, respectively). In addition, assistants measured triceps skinfold thicknesses to the nearest 0.1 mm in the children using Lange skinfold calipers (Lohman et al., 1988). For child measures, BMI-for-age z scores (BAZ) and triceps skinfolds-for-age z scores (TAZ) were calculated based on CDC reference growth curves for age and sex (Addo & Himes, 2010; Kuczmarski et al., 2000). We analyzed both BAZ and TAZ because they may provide complementary information on body size, and it is recommended to examine multiple measures whenever possible (Gundersen et al., 2009). Triceps skinfolds are considered a more valid marker of adiposity (e.g. correlation between triceps skinfolds and dual X-ray absorptiometry (DXA)-assessed fat mass was 0.89 compared to 0.80 for BMI (Tuan & Wang, 2014)); but are subject to greater measurement error. Furthermore, BAZ has been consistently correlated with adiposity, especially for children with higher BMIs (correlation with DXA between 0.85 to 0.96 for those in the BMI-for-age percentile ≥ 85 th (Freedman et al., 2005)). Caregiver BMI was calculated as kg/m^2 . Research assistants were blind to the food insecurity status and dietary information of the children at the time of the anthropometric

assessments. No anthropometric measurements were excluded as potential outliers and no transformations were necessary.

Diet Quality Measures

To obtain information concerning usual dietary consumption of the child outside of Head Start at baseline and at follow-up, we collected multiple 24-hour dietary recalls. Although dietary assessment in this age group is highly subject to error, multiple 24-hour recalls have been recommended as a dietary assessment tool for preschoolers based on a few validation studies of total energy intake (Burrows et al., 2010). Three unannounced 24-hour dietary recalls were collected via phone by trained dietitians from caregivers. We utilized the USDA 5-step automated multiple-pass method, which has been shown to improve accuracy of diet recall (Conway et al., 2004). This occurred over a 2-3 week period, and aimed to include 24-hour recalls from 2 weekdays and 1 weekend day. Caregivers were provided handouts showing child-appropriate portion sizes to assist. To obtain information on consumption while in Head Start, research staff observed and recorded what the children ate during the same weekdays that the caregivers provided 24-hour recall information. Nutrient and caloric content of each food item was calculated with the aid of the USDA Food Composition Database using the Nutrition Data System for Research program (University of Minnesota, Minneapolis, MN). Calories of all foods consumed in the 24-hour period were summed to calculate total energy intake. To estimate usual total energy intake for the time period (separately for baseline and follow-up), all of the valid 24-hour recalls collected during the particular time period were averaged. Similarly, summary variables of food items in servings/day as well as nutrient contents per day for each participant were created by averaging the three 24-hour recalls. Recalls with implausible energy intakes were removed prior to analysis (n=41 of 2925 total recalls) using established criteria

(Rosner, 1983). For the children with implausible energy intakes, diet was assessed by averaging the other recalls. There was 1 child who was completely excluded at the follow-up time point on the basis of all implausible recalls. In order to assess dietary quality, a SAS program was written to calculate a Healthy Eating Index-2010 (HEI) score as previously described (Guenther et al., 2013). We chose HEI as our measure of diet quality because it validly assesses whether an individual's diet complies with the 2010 age-appropriate USDA dietary recommendations (Guenther et al., 2014). In brief, the measure comprises 12 sub-categories including total fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acids, refined grains, sodium, and empty calories. For each category, a score was calculated to reflect the extent to which the participant's diet composition (per 1000 Calories) followed 2010 USDA recommendations for preschool aged children in that category. Finally, all the sub-component scores were summed to create the overall HEI. The HEI ranges from 0 to 100, with 100 representing full adherence to current recommendations.

Other covariates

As a part of the demographic questionnaire administered during the first visit, caregivers provided information on the household composition, his/her race/ethnicity, his/her education, household income from all sources, and receipt of food stamps or any money from public assistance in the previous 12 months. Household composition was categorized as single caregiver household or other. Race/ethnicity was classified as White, non-Hispanic, Black, non-Hispanic, Hispanic, and other. Education was categorized into those who did not graduate from high school, high school graduates or obtained a GED, and those with a post-high school education. Income-to-needs ratio was calculated as the total reported household income divided

by the federal poverty line for a family of the same size during the corresponding year. Receipt of food stamps or any money from public assistance was categorized as yes or no.

Data Analysis

There were 614 children who had household food insecurity information and at least one of the outcome measures (HEI, BMI, or TAZ) at baseline. Of these, 501 (82%) had household food insecurity information at both time points and at least one outcome measure. The analytic sample did not differ from the baseline study population (obesity prevention trial participants) according to the sociodemographic characteristics listed in Table 1 (data available upon request). Given the differential associations by sex observed in the earlier US study among young children (Jyoti et al., 2005), all analyses were stratified by sex. This is also in accordance with other food insecurity literature in this age group as well as literature examining adiposity trajectories (Gundersen et al., 2009; Speirs & Fiese, 2016; Wen et al., 2012). Furthermore, our preliminary models indicated an interaction by sex of the association of food insecurity status change with change in HEI (P , interaction <0.0001) and BMI (p , interaction $=0.07$).

The primary outcomes were changes in BAZ, TAZ, and HEI, considered as continuous variables. The primary exposure was household food insecurity status change. The dichotomous household food insecurity measure from baseline and follow-up was used to classify households into one of four categories: persistently food secure (food secure at both time points), became food insecure (food secure at baseline, food insecure at follow-up), persistently food insecure (food insecure at both time points), and became food secure (food insecure at baseline, food secure at follow-up).

We first examined child and household sociodemographic characteristics according to baseline household food insecurity status. We used Wilcoxon and Chi square tests for hypothesis testing of continuous and categorical predictors, respectively. For caregiver education, we used a Cochran Armitage trend test. In order to assess potential confounders of the relations between change in food insecurity and change in BAZ, TAZ, and diet quality, we examined the associations between baseline household characteristics and changes in food insecurity. For hypothesis testing, we utilized Kruskal Wallis (due to deviations from normality) and Chi square tests of continuous and categorical predictors, respectively.

In bivariate analysis, we assessed the association between household food insecurity status change and change in BAZ, TAZ, or HEI. We utilized linear mixed effects regression models to account for correlation due to repeated measurements and clustering by school. In these models, BAZ, TAZ, or HEI score was the outcome and predictors included indicator variables for household food insecurity status, time of measurement (baseline versus follow-up) and the time*food insecurity status interaction. We used a Wald test of each interaction term to assess whether changes in the outcome differed according to household food insecurity status category, relative to those from persistently food secure households. To test the hypothesis that children from households that became food secure would have differences in BAZ, TAZ and diet quality relative to households that remained food insecure, we set the latter group as the referent. In adjusted analyses, we included indicator variables for caregiver race/ethnicity and caregiver education, and a continuous variable for income-to-needs ratio. These variables were deemed a priori as potential confounders (Kohn et al., 2014). We did not include adjustment for treatment group because changes in food insecurity status were assumed to be independent of treatment arm (confirmed in sensitivity analyses) and because there was not a main effect of intervention

on BMI or overall diet quality. We did not adjust for total energy intake in the models with HEI because total energy intake is already accounted for in the calculation of the score. Finally, adjusting for change in food assistance over follow-up did not alter estimates and was not included in final models; similarly, incorporation of duration of follow-up did not change findings. Linear mixed effects models were run in Stata version 14, and all other analyses were performed in SAS version 9.4.

Supplemental analyses

Because weight gain or loss could arise from a change in total energy intake without any change in diet quality, we considered change in total energy intake as a separate outcome. In addition, because a change in one sub-category of the HEI could be counterbalanced by a change in the opposite direction of another sub-category, we analyzed each sub-category of the HEI as a separate outcome. Supplemental analyses are not shown but available upon request.

RESULTS

The mean $\pm$ SD age of the children at baseline was 4.4 ± 0.6 y. Boys comprised 48% of the sample. At baseline, 37% of households were food insecure and 86% received either food stamps or money from public assistance. Baseline household food insecurity was associated with lower caregiver education, although the trend was not statistically significant ($P_{\text{trend}}=0.06$, Table 1). Baseline household food insecurity was not a statistically significant predictor of baseline child BAZ, TAZ, or HEI. At follow-up, the prevalence of household food insecurity was 30% and 83% of households received food stamps or public assistance. Fifty-four percent of households were persistently food secure, 15% became food secure, 21% were persistently food insecure, and 10% became food insecure. There were no associations between change in food insecurity status over the year and baseline household characteristics, including being a single caregiver household, caregiver race/ethnicity, caregiver BMI, and income-to-needs ratio (Table 2).

Changes in BAZ, TAZ, and diet quality according to changes in food insecurity among girls

The baseline mean $\pm$ SD BAZ score was 0.49 ± 1.10 and the baseline mean $\pm$ SD TAZ score was 0.30 ± 1.06 ; 30.6% were overweight/obese. The average change in BAZ and TAZ over follow-up was -0.02 (95% CI -0.06 to 0.03) and 0.08 (95% CI -0.01 to 0.17), respectively. The change in BAZ over the school year was higher for girls from households that became food insecure compared to girls from households that remained food secure. After adjustment for caregiver race/ethnicity, caregiver education, and baseline income-to-needs ratio, girls whose households became food insecure over the year had a 0.21 higher average BAZ score gain than girls from households that were persistently food secure (95% CI 0.02 to 0.39 ; $P=0.03$). Changes in BAZ among girls from persistently food insecure households were not statistically significantly different from changes in BAZ among girls from persistently food secure

households. Also, changes in BAZ among girls from households that became food secure over the year were not different from BAZ changes among girls from households that were persistently food insecure. Changes in TAZ were not statistically significantly different according to change in household food insecurity in any of the comparisons (see Supplemental Table).

At baseline, the mean $\pm$ SD HEI score among girls was 60.8 ± 11.0 points (range 31.4-92.9). This was statistically significantly higher than the boys' overall score ($p=0.01$), reflecting higher scores in the whole fruit, seafood, and refined grain subcategories. The average change in HEI score over the year for girls was -2.0 points (95% CI -3.5 to -0.5). Changes in HEI scores over the year were not different when comparing girls from households that became food insecure or who were persistently food insecure to girls from households that were persistently food secure. However, girls from households that became food secure over the year had improved HEI scores while girls from households that were persistently food insecure over the school year had declines in HEI score (Table 3). After adjustment for caregiver race/ethnicity, caregiver education, and baseline income-to-needs ratio, girls from households that became food secure had an average 9.1-point improvement in HEI score over the year relative to the HEI changes among girls from households that were persistently food insecure (95% CI 3.1 to 15.0; $p=0.003$; Table 4). The sub-component food groups that showed the most robust improvements were total fruit scores (1.4 points, 95% CI 0.5 to 2.4; $p=0.003$) and fatty acid scores (1.6 points, 95% CI 0.1 to 3.1; $P=0.03$). In supplemental analyses, changes in total energy intake from baseline to follow-up did not statistically significantly differ according to change in household food insecurity in any between-group comparisons.

Changes in BAZ, TAZ and diet quality according to changes in food insecurity among boys

At baseline, boys had a mean $\pm$ SD BAZ score of 0.74 ± 1.23 and a mean TAZ score of 0.32 ± 1.10 ; 39.2% were overweight/obese. The average change in BAZ among all boys from baseline to follow-up was -0.03 (95% CI -0.07 to 0.02), and in TAZ was 0.16 (95% CI 0.03 to 0.28). Neither the changes in BAZ nor TAZ over the school year depended on household food insecurity change status over the year for any comparison (Table 5 and Supplemental Table).

Boys had a mean $\pm$ SD HEI score at baseline of 58.6 ± 10.9 (range 22.5-86.1). The average change in HEI score over the year was 0.4 points (95% CI -1.0 to 1.9). Changes in HEI scores over the school year did not differ according to household food insecurity status change. In supplemental analyses, boys from households that became food insecure had decreases in total energy intake relative to boys from persistently food secure households (-316 Calories, 95% CI -530 to -102; adjusted P=0.004).

DISCUSSION

In this population of low SES Head Start preschoolers from Michigan, we found that girls from households that became food insecure had higher gains in BMI compared to girls from households that were persistently food secure. In addition, we found that girls from households that became food secure over the year had statistically significant diet quality improvements compared to girls from households that were food insecure the entire year. Among boys, there were decreases in total energy intake, although not diet quality, when comparing boys from households that became food insecure to those who were persistently food secure.

The average BMI in this US study population was slightly higher than nationally representative estimates (Guerrero et al., 2016), although lower than estimates from Head Start populations in Alabama and Texas (Acharya et al., 2011). Similar to several other cross-sectional studies among US children, baseline household food insecurity was not related to child BMI measured at the same time (Eisenmann et al., 2011; Gundersen et al., 2009; Kaur et al., 2015). However, very few studies have looked at longitudinal associations between food insecurity and BMI or triceps skinfold thicknesses (Burke et al., 2016; Dubois et al., 2006; Jones & Frongillo, 2007; Jyoti et al., 2005; Metallinos-Katsaras et al., 2012), and we only identified one study that specifically examined the relations between concurrent changes in food insecurity and BMI in children (Jyoti et al., 2005). In that US study and in ours, children from households that became food insecure had higher gains in BMI than children from households that became secure. These findings corroborate the notion that an anticipation of food shortage may be linked to gains in adiposity. However, in the previous study, the association was only evident among boys whereas we found an association only among girls. Nonetheless, a recent meta-analysis of the current food insecurity literature suggested that there are relations between food insecurity and BMI

among girls but not boys (Speirs & Fiese, 2016). An even more recent longitudinal study found that girls from food insecure households had higher gains in BMI from Kindergarten through eighth grade, whereas there was no association for boys (Burke et al., 2016).

Mechanisms are speculative, but one reason for the sex-specific findings could be related to different experiences of food insecurity. This could be due to sex-dependent parental feeding practices or to food choices made by the children themselves. Research shows that even when parents reported shielding their children from food insufficiency, the children in the house were usually aware of the situation and reported changing their dietary behaviors (Fram et al., 2011). Furthermore, girls could perceive and/or react to the stress in the household environment differently than boys (Nettle et al., 2016; Ruttle et al., 2014). In support, whereas girls in our study gained body mass, boys in households that became food insecure actually had reductions in total energy intake compared to those from persistently secure households. The sex-specific association is also plausible from a biological and evolutionary perspective. For females, a lack of nutrition is detrimental for reaching sexual maturity and ultimately, sustaining pregnancy. Thus, the ability to gain weight during periods of future food uncertainty might have been evolutionarily favored for females. This could also explain why there is a more robust association between food insecurity and overweight/obesity among adult females than men (Nettle et al., 2016). Although this association is not consistent either (Jones & Frongillo, 2007), it seems to be more evident during vulnerable periods such as pregnancy (Laraia et al., 2010).

It is of note that the associations between changes in BMI and changes in food insecurity did not mirror the associations between changes in food insecurity and changes in diet. For example, although we found BMI gains among girls from households who became food insecure compared to persistently food secure, we did not find declines in diet quality. In addition,

although boys in households who became food insecure had reductions in caloric intake compared to persistently food secure households, there were not corresponding reductions in BMI. One potential explanation for a change in BMI without a change in diet or vice versa could be a change in physical activity or sleeping patterns (Carter et al., 2011). Another plausible explanation is measurement error in the assessment of diet. One reason is that caregivers may have trouble answering accurately or objectively; for instance, caregivers with food procurement difficulties might more favorably report their child's at-home consumption out of concern of a judgmental reaction by the interviewer. Another possibility is that the three 24 hour recalls were not a true representation of the longer-term diet.

Albeit the potential for measurement error, the average HEI scores were very similar to nationally representative data collected around the same time (Ford et al., 2016; Tester et al., 2016). The average HEI scores in our population, depending on sex and food insecurity status change, ranged from 55.3 to 62.3; which is a little higher than the average HEI of US children aged 2-5 y (46.5)(Ford et al., 2016), but close to the nationally-representative average score of 58.3 for children whose households received WIC assistance (Tester et al., 2016). The study estimates also corroborate a recent nationally representative report of overall poor dietary quality among pre-school aged US children (Banfield et al., 2016). This is concerning because diet quality tends to decline as children age (Carlson et al., 2001; Jarman et al., 2015); this was true for most girls in our study (all girls except those who became food secure), although not for boys over this time period.

We did not find statistically significant differences in BAZ or TAZ changes when comparing girls from persistently food insecure household to persistently food secure households. This could mean that persistently food insecure households have different mechanisms of coping

than families who have more recently transitioned to food insecurity. We also did not find differences in BAZ or TAZ changes when comparing girls from households that became food secure to those from persistently food insecure households. It is possible the follow-up period was not long enough to observe differences between these groups. Finally, there were no statistically significant differences in triceps skinfold thickness change according to household food insecurity status. This could be related to lower precision in skinfold measurement than BMI (within-individual coefficient of variation in the study sample was 3.5% for triceps skinfold measures compared to 0.15% for height and 0.09% for weight). In addition, the change in triceps skinfolds from ages 4 to 6 y is expected to be relatively minimal (Addo & Himes, 2010) compared to BMI changes over these ages (Kuczmarski et al., 2000).

Our study has several strengths. One is having multiple measurements of the exposure and outcome measurements, which enabled us to analyze changes, a stronger study design for causal inference than cross-sectional analysis. Another is the use of mixed effects models, which take into account repeated measurements and clustering by school to yield valid standard errors. In addition, the analytic sample did not differ from the original study sample, which indicates a lower probability of selection bias introduced at the time of analysis. There are also limitations. First, we do not know when changes in household food insecurity occurred over the year; thus, we cannot say whether changes in household food insecurity preceded changes in BMI and diet quality. Although speculative, it is possible that increased consumption of the children in the household could cause caregivers to worry about an impending food shortage and change their food insecurity responses as a result. Generalizability of the findings to other low SES populations may be hindered due to the fact that these children were enrolled in Head Start and had access to at least one free meal per day; associations may be different among preschool-aged

children who consume all meals at home. There is also potential for confounding by unmeasured variables. It is possible that changes in reported food insecurity were a proxy for an unmeasured household level change that occurred over the year, such as a job loss/gain, illness, or family resiliency, that was independently related to changes in child diet and BMI. Also, we were not able to assess each child's perception of stress surrounding food procurement in the household. Furthermore, although we asked caregivers whether the children in the household ever went without food, the number of affirmative responses was so low that we were not powered to examine these variables. Finally, due to limitations of BMI as a measure of adiposity, it is possible that changes in BMI were not reflective of changes in fat mass.

In conclusion, one-quarter of the households in this population of low SES Michigan preschoolers experienced changes in food insecurity status over the year, suggesting that household food security in this population is not stable. Preschool-aged girls living in households during transitional periods from food security to insecurity may be especially vulnerable to weight gain. This provides further evidence that children are not shielded from all aspects of household food procurement difficulties or perceived difficulties, especially children in households who have recently transitioned or are transitioning into food insecurity. In order to inform public health practice, our findings could be viewed from the perspective of family resilience theory. From this perspective, highly resilient families would be better equipped to cope with the physical and emotional difficulties of transitions into food insecurity. Thus, support programs for households dealing with food insecurity transitions or those at risk of transitioning could be designed with this framework in mind, which would incorporate belief systems, relational and structural support systems, and communication processes. Continued research efforts should focus on identifying the most effective strategies for promoting the health

432 of children in households undergoing transitions into food insecurity as well as those with
433 persistent food insecurity. On a broader scale, study results emphasize the continued need for
434 national policy aimed at decreasing the economic inequalities that contribute to poverty and
435 concomitant food insecurity.

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Table 1. Baseline household and child characteristics according to baseline food insecurity status

	Baseline Household Status		P ¹
	Food Secure N=350	Food Insecure N= 151	
Single caregiver household (Yes/No)	31.9	27.1	0.26
Primary caregiver race/ethnicity			0.40
White, non-Hispanic, %	60.2	60.2	
Black, non-Hispanic, %	29.8	26.5	
Hispanic, %	6.7	6.6	
Other, %	3.5	6.6	
Primary caregiver BMI (kg/m ²), mean $\pm$ SD	31.3 $\pm$ 8.5	32.7 $\pm$ 9.1	0.15
Primary caregiver education			0.06
Did not graduate HS, %	13.4	19.6	
HS graduate/GED, %	32.1	33.0	
Post-HS education, %	54.4	47.5	
Household income-to-needs ratio, mean $\pm$ SD	0.87 $\pm$ 0.58	0.82 $\pm$ 0.44	0.99
Child's BMI-for-age z score ²	0.57 $\pm$ 1.06	0.59 $\pm$ 1.30	0.93
Child's triceps skinfold-for-age z score ²	0.25 $\pm$ 1.0	0.33 $\pm$ 1.1	0.53
Child's Healthy Eating Index score	60.2 $\pm$ 11.5	60.5 $\pm$ 9.9	0.72

Footnotes to Table 1

¹ For continuous variables, p-values are from Wilcoxon tests. For categorical variables, p-values are from a Chi-square test. For caregiver education, p-value is from Cochran Armitage test.

² Based on CDC reference

Table 2. Changes in household food insecurity over one school year among 501 low-SES Michigan preschoolers, according to baseline household characteristics

Baseline household characteristics	Food insecurity status over one school year				P ¹
	Persistently food secure	Became food insecure	Persistently food insecure	Became food secure	
	N=272	N=76	N=48	N=105	
Single caregiver household	32.0	31.3	24.8	30.3	0.59
Primary caregiver race/ethnicity					0.68
White, non-Hispanic, %	60.3	59.6	61.9	57.9	
Black, non-Hispanic, %	29.8	29.8	23.8	30.3	
Hispanic, %	6.3	8.5	5.7	7.9	
Other, %	3.7	2.1	8.6	4.0	
Primary caregiver education					0.50
Did not graduate HS, %	12.6	19.2	18.3	21.3	
HS graduate/GED, %	32.5	29.8	33.7	32.0	
Post-HS education, %	55.0	51.1	48.1	46.7	
Income-to-needs ratio, mean $\pm$ SD	0.89 $\pm$ 0.58	0.78 $\pm$ 0.55	0.80 $\pm$ 0.42	0.85 $\pm$ 0.46	0.56

¹For categorical variables, p-values are from a Chi-square test. For income-to-needs ratio, p-value is from a Kruskal Wallis test.

Table 3. Changes in BMI-for-age z scores, triceps skinfold-for-age z scores, and diet quality scores of 501 low-SES Michigan preschoolers at baseline and follow-up of one school year, according to changes in household food insecurity

Household food insecurity change status	BMI-for-age z scores							
	Girls				Boys			
	N	Baseline ($\pm$ SD)	N	Follow-up ($\pm$ SD)	N	Baseline ($\pm$ SD)	N	Follow-up ($\pm$ SD)
Persistently food secure	132	0.47 ± 1.0	135	0.44 ± 1.0	133	0.68 ± 1.1	130	0.64 ± 1.1
Became food insecure	29	0.57 ± 1.1	27	0.74 ± 1.0	19	0.57 ± 1.1	19	0.49 ± 1.0
Persistently food insecure	61	0.55 ± 1.1	61	0.56 ± 1.0	43	0.61 ± 1.4	41	0.67 ± 1.2
Became food secure	37	0.40 ± 1.3	33	0.22 ± 1.3	39	0.83 ± 1.4	39	0.68 ± 1.4
Triceps skinfold-for-age z scores								
Persistently food secure	129	0.27 ± 1.0	130	0.33 ± 1.1	130	0.21 ± 1.0	130	0.44 ± 1.2
Became food insecure	61	0.36 ± 1.1	27	0.79 ± 1.1	18	0.30 ± 1.0	19	0.43 ± 1.0
Persistently food insecure	28	0.33 ± 1.0	61	0.33 ± 1.0	42	0.24 ± 1.0	41	0.29 ± 1.2
Became food secure	37	0.21 ± 1.1	30	0.20 ± 1.2	38	0.54 ± 1.2	37	0.62 ± 1.5
Healthy Eating Index score								
Persistently food secure	129	62.3 ± 11.3	126	59.2 ± 11.7	129	57.7 ± 11.6	128	58.9 ± 12.0
Became food insecure	19	61.4 ± 11.5	26	58.0 ± 10.5	19	59.4 ± 10.3	19	61.6 ± 10.6
Persistently food insecure	42	61.6 ± 10.2	60	55.3 ± 11.1	39	61.4 ± 9.8	42	58.3 ± 11.2
Became food secure	36	59.4 ± 10.5	34	62.0 ± 9.1	37	58.9 ± 8.7	36	58.3 ± 11.0

Table 4. Changes in BMI-for-age *z* scores (BAZ) and diet quality among 263 low-SES Michigan preschool girls over one school year, according to household food insecurity status over the same time period

Household food insecurity change status	Change in BAZ							
	Unadjusted difference in change (95% CI) ¹	P ²	Adjusted difference in change (95% CI) ^{1,3}	P ²	Unadjusted difference in change (95% CI) ¹	P ²	Adjusted difference in change (95% CI) ^{1,3}	P ²
Persistently food secure	Reference		Reference					
Became food insecure	0.18 (0.01, 0.35)	0.04	0.21 (0.02, 0.39)	0.03				
Persistently food insecure	0.05 (-0.08, 0.17)	0.46	0.04 (-0.09, 0.17)	0.53	Reference		Reference	
Became food secure					-0.14 (-0.32, 0.04)	0.12	-0.15 (-0.34, 0.03)	0.10
Change in Healthy Eating Index score								
Persistently food secure	Reference		Reference					
Became food insecure	0.7 (-4.8, 6.3)	0.11	0.1 (-5.8, 5.9)	0.97				
Persistently food insecure	-3.3 (-7.2, 0.7)	0.79	-3.6 (-7.7, 0.5)	0.08	Reference		Reference	
Became food secure					8.4 (2.9, 13.9)	0.003	9.1 (3.1, 15.0)	0.003

Footnotes to Table 4

¹From a linear mixed effects regression model with continuous BAZ or Healthy Eating Index score as the outcome and predictors that included indicator variables for household food insecurity status, time of measurement and the time*food insecurity status interaction.

All models accounted for repeated measurements and clustering by school.

² From a Wald test

³ Adjusted for primary caregiver race/ethnicity (reference group=White, non-Hispanic), primary caregiver education (reference group=post-HS education), and baseline income-to-needs ratio (centered at mean).

Table 5. Changes in BMI-for-age *z* scores (BAZ) and diet quality among 238 low-SES Michigan preschool boys over one school year, according to household food insecurity status over the same time period

Household food insecurity change status	Change in BAZ							
	Unadjusted difference in change (95% CI) ¹	P ²	Adjusted difference in change (95% CI) ^{1,3}	P ²	Unadjusted difference in change (95% CI) ¹	P ²	Adjusted difference in change (95% CI) ^{1,3}	P ²
Persistently food secure	Reference		Reference					
Became food insecure	-0.02 (-0.21, 0.18)	0.85	-0.03 (-0.24, 0.18)	0.77				
Persistently food insecure	0.08 (-0.07, 0.22)	0.30	0.10 (-0.05, 0.25)	0.18	Reference		Reference	
Became food secure					-0.17 (-0.34, 0.00)	0.06	-0.17 (-0.35, 0.02)	0.08
Change in Healthy Eating Index score								
Persistently food secure	Reference		Reference					
Became food insecure	0.9 (-4.8, 6.6)	0.76	0.9 (-5.4, 7.2)	0.78				
Persistently food insecure	-2.3 (-6.7, 2.1)	0.30	-2.5 (-7.2, 2.2)	0.30	Reference		Reference	
Became food secure					2.0 (-3.4, 7.4)	0.47	1.3 (-4.4, 7.1)	0.65

Footnotes to Table 5

¹From a linear mixed effects regression model with continuous BAZ or Healthy Eating Index score as the outcome and predictors that included indicator variables for household food insecurity status, time of measurement and the time*food insecurity status interaction. All models accounted for repeated measurements and clustering by school.

² From a Wald test

³ Adjusted for primary caregiver race/ethnicity (reference group=White, non-Hispanic), primary caregiver education (reference group=post-HS education), and baseline income-to-needs ratio (centered at mean).