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Application of Noninferiority Tests to Examine the Food Insecurity-Obesity Relationship in Children

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Abstract

This study applies non-inferiority testing to assess the relationship between child weight and food security status in a sample of 808 children between 3 and 5 years old who were attending an urban, state-funded preschool program. Most families were African American (72.3%). Analyses were conducted using non-inferiority testing to evaluate the overweight-food security association. Odds of being overweight in the Food Insecure (FI) group were .643 (95% CI .525 to .788) while odds from the Food Secure (FS) group were .570 (95% CI .464 to .697), OR=1.127 ($P=.004$). These findings held across sub-groups of gender, race, and family conflict. Children whose parent indicated education beyond high school showed a reversal with FI odds of overweight less than FS odds (OR=.663). As illustrated in this study, non-inferiority testing provides an alternative analytic approach to examining the association between FI and weight in children.

Keywords

Obesity; Food Insecurity; Children

Introduction

In 2014, 17.4 million households in the US experienced food insecurity, including 3.7 million households with children.¹ Food insecurity (FI) is related to poorer health, more frequent hospitalizations, and higher rates of developmental problems for children.^{2–4} This may be attributable to both the limited quantity of healthy food available to children as well as intake of more calorie-dense, nutrient-sparse foods that are less expensive.⁵ Concern about food quality for FI families is supported by studies that find children in FI households were significantly less likely to consume fruits and vegetables and more likely to consume soda and processed foods.^{6,7}

The relationship between FI and weight has been explored in both adult and child samples. For adults, the literature clearly supports an association between FI and excess weight. For example, a recent review linked FI with overweight among adults, particularly for women.⁸

Similarly, the Behavioral Risk Factor Surveillance System Study of 66,553 adults from 12 states found that adults who experienced FI had 32% increased odds of being obese compared to food secure adults.⁹ Researchers have proposed that dietary quality and the cycle of food acquisition are potential reasons for this paradoxical relationship.¹⁰

The association between FI and weight for children has been less consistent in the literature. A Social Policy Report from the Society of Research in Child Development stated that research “has definitely shown that there is no relationship between food insecurity and obesity among children”.¹¹ This claim was based on analyses of the National Health and Nutrition Examination Survey data from 1999–2002¹² and 2001–2004¹³ which found no direct association between overweight and food security among children 3 to 17 years in probit and logistic regression models. A later systematic review agreed that there is little support for a linear relation between FI and overweight for children.⁸ Further, Larson and Story report that only 6 of 25 available studies report a link between child weight and FI.¹⁴ These findings have contributed to conclusions that food insecurity does not consistently contribute to excess weight among children.

More recent cross-sectional studies among preschool-aged children in New Mexico ($N=347$),¹⁵ Illinois ($N=438$),¹⁶ Connecticut ($N=222$)¹⁷ and the UK⁶ also found no relation between child weight and food insecurity. However, Speirs and colleagues observe that a “noteworthy proportion of food insecure children were overweight or obese.”¹⁶ In the Trapp¹⁷ sample, 45% of food insecure children were overweight or obese; 29.5% of food secure children were overweight or obese. Similarly, Vedovato and colleagues found a combined rate of obesity and overweight of 43.1% among food secure children, 37.9% among children with FI without hunger, and 45.9% among children experiencing FI with hunger. Study conclusions were that there were no significant differences by food security status.¹⁸ Gunderson found that up to 57% of food insecure children were overweight or obese depending on the measure of obesity used.¹³ Clearly, children who experience FI are not protected from excess weight even in studies where statistical conclusions do not support a relationship between these factors.

Other studies have demonstrated a relationship between FI and weight in children. For example, Casey et al. found that FI was significantly associated with child overweight for children between 12 and 17 in logistic regression models using NHANES data from 1999–2002.¹⁹ Similarly, Holben and Taylor found that, after controlling for age, race, and sex, overweight and obesity were significantly more prevalent among 12 to 18 year olds from FI households using logistic regression models of NHANES data from 1999–2006.²⁰ Yet another study of NHANES data from 2001–2010 found that personal-level FI was associated with greater rates of obesity among 6 to 11 year-old children.²¹ Further, in a separate study of younger children ($N=8,493$), girls between age 2 and 5 in households with FI who experienced hunger had higher rates of overweight than counterparts in food secure households.²²

The mixed results and inconsistent conclusions of studies on the association between FI and weight in children raise important questions, especially since high rates of overweight and obese children exist across different food security statuses in a variety of samples. Given that

the definition of food insecurity is the absence of “consistent, dependable access to enough food for active, healthy living,”²³ lower weight among children who experience FI might be expected. However, there may be several factors in children that make the relationship between FI and weight more complex (e.g., developmental stage, growth rate) than in adults. Further, the factors recognized as complicating this relationship among adults (e.g., food quality, food acquisition cycle)¹⁰ may also impact children. Regardless, the co-occurrence of FI and excess weight is a concerning and puzzling relationship.

Analyses of the FI and overweight association to this point have been conducted using a traditional null hypothesis (i.e., equal rates of overweight and obesity between groups), with regression analysis highlighting effects when a variable contributes significantly to the model’s ability to describe change in the outcome. In these models, to have a significant finding, food insecure individuals must be overweight and obese at much *higher* rates than food secure peers. In the current study, we employed non-inferiority tests as an alternate approach to examining the relationship between child FI and weight.

Non-inferiority tests are suitable to study the relationship between weight and food security for children because this approach recognizes that even *equal* rates of overweight and obesity for FI children and FS children implicate non-ignorable conclusions. Use of non-inferiority tests allowed us to test the null assumption that rates of overweight/obesity are higher in FS children than FI children. If we rejected the null, we concluded that children with inadequate access to food experience similar levels of overweight compared to children with adequate access to food. This conclusion would lead to different policy implications and directions for future research than does a traditional approach which concludes that FI and weight are not related. Thus, our study applied the use of this alternative analytic strategy in the study of the relationship between FI and child weight.

Methods

Procedure and Participants

The Family Map Inventory (FMI) was implemented in a Southern state in 10 state-funded preschool centers in a metropolitan area. Children in families with incomes at 200% of poverty or below are eligible for state-funded preschool. Data were collected across three school years (2011–2012, 2012–2013, 2013–2014) by early childhood educators (ECEs) trained in the use of the FMI. Interviews were conducted at parent-teacher conferences at the beginning of the school year. Trained program staff collected child height and weight records as part of ongoing monitoring of child health indicators. De-identified FMI, height, and weight records were extracted from agency systems under protocols approved by the [Removed for Blinded Review] Institutional Review Board. Estimates of the rate of food insecurity in the state which this study was conducted range from 8.1% to 19.9%.¹

Measurements

Family Map Inventory.—The FMI is a semi-structured interview designed and validated for use with pregnant mothers (PN), and parents of infants and toddlers (IT) or children age three to five (EC).²⁴ The EC- FMI was used in this study to aid educators in identifying

areas of concern and strength to best design interventions and reduce risk conditions for families. The EC- FMI includes 12 modules which assess a range of topics important for child development. Of these, two modules included assessments of parent education and family conflict which have moderated the FI and weight relationship in other studies^{12,25} and are included as covariates in our study. FMI questions on education focus on the highest education attained by the primary caregiver. Low parent education is determined as high school completion or less; high parent education indicates some level of additional schooling such as a technical certification, associate's degree, or higher. FMI questions on family conflict were based on 14 questions in 3 sections measuring family dynamics to incorporate degree of partner conflict, overall family conflict and supportiveness, and stress specifically due to parenting. If two or more items within the same section of either partner conflict or overall family conflict and supportiveness, or three or more items within parenting stress indicated risk, families were designated as having high family conflict consistent with the FM scoring convention.

Food Insecurity.—The Family Map includes two questions from the Household Food Security Survey (HFSSM).²⁶ Two-item assessments of FI, including the items selected for this survey, have demonstrated appropriate levels of sensitivity and specificity as well as convergent validity in previous studies and in community settings.^{27,28} Reflecting on the previous year, parents indicated agreement with two statements: (a) “The food that you bought just didn’t last and you didn’t have money to get more,” and (b) “You or others in your household cut the size of your meals or skipped meals because there wasn’t enough money for food.” Parents indicated if these experiences were *Never True*, *Sometimes True* or *Often True*. Indicating that either item was *Sometimes* or *Often True* received a designation of Food Insecure (FI). Internal consistency (i.e., Cronbach’s alpha) for the two-items in this sample was .92.

Body Mass Index.—Height and weight assessments were logged multiple times during the school year by trained program staff. For the purpose of our study, the assessment closest in time to the FMI was used. The average lag in measurement between the FMI and BMI was 1.67 months (SD 4.77 months). Using height, weight, gender, date of birth, and date of assessment, the research team calculated BMI-for-Age according to the CDC formula.²⁹ BMI scores were converted to percentiles using the CDC BMI-for-age charts, 2 to 20 years. Children with a BMI at or greater than the 85th percentile were classified as overweight, while those with BMI at or greater than the 95th percentile were classified as obese. We collectively refer to children in both groups as overweight.

Analysis

Analysis included non-inferiority tests conducted with R version 3.2.2.³⁰ The non-inferiority test is significant if the ratio in question is greater than a pre-determined margin which has been deemed insignificant. A key component in non-inferiority testing is the *a priori* specification of this insignificant margin of difference (δ). There is yet no consensus how to define this margin, though the need for it to be meaningful suggests derivation based on clinical judgment³¹ or such to maintain statistical properties.³² For this study, the margin was taken from the lower bound of a 95% confidence interval for the within group odds ratio

of being overweight in the food-secure group and adjusted for group size differences between food security groups. T-tests for the odds ratio were conducted with formulas from Chow, Wang, and Shao³³ taking into account recent recommendations to include confidence interval comparisons,³⁴ 95% confidence intervals for overweight odds in each food security group are presented even as this presents a conservative approach.³⁵ In both cases, intervals were derived using Monte Carlo methods adaptive to the varying distributions between groups, this adaptability being considered more appropriate than a constant non-inferiority margin.³⁶

Data integrity included tests of group composition in addition to outliers. The potential confounders of child gender, race, parent education, and family conflict are often included as covariates when performing regression^{22,25,37} and certain populations report higher prevalences of obesity.³⁸ Fisher exact tests evaluated food security groups for significant differences in these characteristics. Additionally, non-inferiority tests stratified these demographics as possible to control for how differences may impact the food security-overweight relationship. Outliers based on BMI z-score were determined from Tukey's Hinge Inner Quartile Range (IQR) and extreme outliers (N=3) - those more than 3 IQR above the 75th percentile or below the 25th percentile - were removed as implausible BMI values and likely errors in measurement.

Results

Table 1 describes overall gender, race, and noted socioeconomic characteristics of the sample as well as food security and weight status by these characteristics. Children were a majority non-Hispanic African American (72.3%), and the sample included slightly more girls (53.6%) than boys. More parents (54.9%) showed risk for low education, completing a high school degree or less. Further, 38.7% of families reported experiencing high levels of family conflict in at least one area of partner conflict, overall family conflict, lack of support, and parent stress. In the total sample, the prevalence of food insecurity was 11.4%. Children were overweight or obese in 36.6% of the population, appearing at a higher rate (39.1%) in the food insecure group than in the food secure group (36.3%). Demographic composition across food security status showed no difference between FI and FS groups for gender, race, or parent education with Fisher exact tests. Presence of family conflict showed a significant disparity between groups with those experiencing high levels of conflict more likely to also be food insecure (OR=4.29, $P<.01$).

Results of non-inferiority analyses are presented in Table 2. In this study, children in the food-insecure group presented with a higher rate of being overweight than food-secure peers. While it does not appear this difference is sufficient to infer higher rates of overweight for food insecure children in general, there is significant evidence to imply non-inferior rates. Odds of being overweight in the FI group were .643 (95% CI .525 to .788) while odds from the FS group were .570 (95% CI .464 to .697), OR=1.127 ($P=.004$). These findings hold across the majority of the stratified subgroups representing different familial aspects often included as covariates. Significant non-inferior odds for overweight were found for male (OR=1.207, $P=.003$) and female (OR=1.144, $P=.005$) children, non-Hispanic white (OR=.792, $P=.023$), non-Hispanic African American (OR=.910, $P=.037$), and Hispanic

(OR=1.655, $P<.001$) children, those experiencing high (OR=.970, $P=.023$) or low (OR=1.301, $P=.002$) family conflict, and those whose parents indicated low educational attainment (OR=1.551, $P<.001$). That is, in all these sub-groups, FI children exhibited a statistically similar to greater proportion of overweight as FS children.

Children whose parent indicated education beyond high school showed a reversal with FI odds of overweight less than FS odds (OR=.663). That is, non-inferiority was not found for this subgroup, and FS children in high education homes exhibited much higher rates of overweight than FI children in high education homes. This suggests parent education as a moderating factor of the relation between FI and child weight.

Discussion

The purpose of this study was to demonstrate the use of a novel but appropriate hypothesis formation and analysis approach for examining the link between overweight and FI in children. Overall proportions of FI (11.4%) and overweight or obese (36.6%) were consistent with national estimates in children of this age and income group,^{1,39} making this an appropriate sample in which to highlight the utility of the NI approach. Further, our study findings are consistent with a number of other studies which found high proportions of overweight and obesity among FI children.^{13,19,40,37} In fact, the proportion of overweight was higher among FI children in the overall sample. This held true for the sub-groupings of children from low parent education homes, from homes with low conflict levels, for both males and females, and those of Hispanic ethnicity.

NI findings illustrate that FI children do not present with overweight significantly less than their FS counterparts. That is, they exhibit overweight at least at equivalent rates to their FS counterparts, even across a range of family characteristics- a determination which cannot be formally made from lack of significance in regression models. When typical analytic approaches do not reach an unexpected outcome (FI = greater overweight), researchers make strong and potentially misleading claims such as “food insecurity is not associated with childhood obesity”.¹³ However, the NI approach as used in this study allows for the study of the co-occurrence of FI and overweight based on what we would expect to observe (i.e. less food = lower weight). Further, the findings of this approach (compared to the traditional approach in the literature) helps to understand how child food-insecurity is “not associated with overweight in low-income children” while still “food insecurity and overweight coexist” in the same sample.³⁷

A strength of this study relative to other large studies of the link between child weight and FI (e.g., NHANES) was our design to specifically examine family level measurements, linking relevant parent data (e.g., education, family conflict) with child BMI data. Our findings suggest that this is an important link given the differential association between weight and FI by parent education. That is, proportion of overweight across food security groups was different in high parent education homes compared to low parent education homes and was in line with natural expectations about how access to food influences weight. These findings are consistent with previous studies which found significantly higher rates of obesity with lower levels of maternal education.²⁵ However, the lack of extended demographic

stratification in NI testing (i.e., gender, race) should be noted given other studies have observed the importance of these factors and include them as covariates even when examining a moderated interaction between FI and overweight through regression. That is, a larger study might examine the FI- overweight relationship under simultaneous stratifications of child gender and family conflict which may be thought of as analogous to a 3-way interaction in regression.

This study is not without limitations. First, the majority of children in our sample (72.3%) were African American. While racial differences were not noted in the composition of food security groups, the NI approach should be replicated in additional racially diverse samples. Relatedly, we were not able to stratify NI tests by the full range of sub-groups (i.e. non-Hispanic African American with high family conflict) because the limited size of some sub-groups led to unstable confidence interval estimates.

Implications.—Our findings indicate the importance of further exploration into the factors that lead children in food insecure households to experience similar rates of excess weight. Future studies should consider employing the NI approach to study of the relationship between FI and child weight and examine dietary quality as a mediator between FI and overweight. For example, children with FI and low acculturation had lower BMIs than children in families with FI but high acculturation.⁴¹ When traditional statistical approaches do not yield a significant relationship between FI and child weight, these type of important mediational processes will be less likely to be examined.⁴² Some of the same processes that lead to greater weight in FI adults may be operating in FI children. Additional years allow for children who were/are FI to surpass children who were/are FS in weight leading to the more consistent results regarding the association of FI and weight observed in adults.

In sum, this study has offered an alternative analytical approach to the study of overweight among FI children. In the context of firm statements about the lack of a relationship between FI and weight in children, this study illustrates a more useful technique to methodological examinations of the shared experience of FI and excess weight. Our study also demonstrates how moderators could be tested within a non-inferiority approach.

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Table 1.

Sample proportions by food security and weight status

	Overall (N= 808)	Food Insecure (N=92)	Food Secure (N=716)	Not OW/Obese (N= 512)	OW/Obese (N= 296)
Proportion of Sample				-	-
<i>Overall</i>		.391	.363	.634	.366
<u>Education</u>					
<i>High Parent Education</i>	.451	.286	.376	.633	.367
<i>Low Parent Education</i>	.549	.451	.346	.641	.359
<u>Family Conflict</u>					
<i>High Family Conflict</i>	.387	.387	.394	.607	.393
<i>Low Family Conflict</i>	.613	.407	.346	.651	.349
<u>Gender</u>					
<i>Male</i>	.464	.424	.379	.617	.383
<i>Female</i>	.536	.353	.323	.673	.327
<u>Ethnicity</u>					
<i>White</i>	.099	.400	.457	.550	.450
<i>African</i>	.723	.322	.343	.659	.341
<i>American</i>					
<i>Hispanic</i>	.106	.533	.409	.570	.430
<i>Other/NA</i>	.072	.625	.380	.586	.414

Table 2.

Stratified non-inferiority tests of overweight odds ratio between food security groups

	Odds Ratio (8^I , p-value)	Group Odds (95% CI)
		<i>Food Insecure</i> <i>Food Secure</i>
Overall	1.127 (.616, .004)	.643 (.525, .788) .570 (.464, .697)
High Parent Education	.663 (.452, .164)	.400 (.280, .550) .603 (.444, .817)
Low Parent Education	1.551 (.516, <.001)	.821 (.622, 1.081) .530 (.392, .702)
High Family Conflict	.970 (.542, .023)	.632 (.453, .855) .651 (.467, .901)
Low Family Conflict	1.301 (.395, .002)	.688 (.528, .884) .528 (.405, .688)
Child Male	1.207 (.435, .003)	.737 (.545, .989) .610 (.442, .821)
Child Female	1.114 (.505, .005)	.545 (.399, .724) .477 (.351, .626)
Child White	.792 (.200, .023)	.667 (.333, 1.222) .842 (.429, 1.500)
Child African American	.910 (.540, .037)	.475 (.364, .604) .522 (.404, .669)
Child Hispanic	1.655 (.272, <.001)	1.143 (.593, 2.071) .690 (.344, 1.263)

^I Non-inferiority margin adjusted for differences in food security group size