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Household socioeconomic status modifies the association between neighborhood SES and obesity in a nationally representative sample of first grade children in the United States

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ABSTRACT

Both low family socioeconomic status (SES) and low neighborhood SES have been associated with higher levels of childhood obesity. However, little is known about how these two factors operate together. The purpose of this study was to determine if the association between neighborhood SES and obesity varies across household SES. We used the first-grade round of the Early Childhood Longitudinal Study, Kindergarten Class of 2011 (ECLS-K:2011). Household SES was defined based on income, education, and occupation. Neighborhood SES was defined by the percent of households living in poverty in the child's school district. Log-binomial regression models estimated the association between neighborhood SES and obesity and tested whether this association varied by household SES. We found the association between neighborhood SES and obesity varied significantly by household SES (p-interaction = 0.002). For children in the lowest tertile of neighborhood SES, prevalence of obesity was not statistically significantly different comparing children with low, middle or high household SES (Predicted probability $(PP)_{lowest}$ 0.20 (95% CI: 0.17, 0.23), PP_{middle} 0.21 (95%CI: 0.18, 0.24), $PP_{highest}$ 0.16 (95%CI: 0.12, 0.20)). Conversely, within the highest and the middle tertiles of neighborhood SES, children with high household SES have significantly lower prevalence of obesity compared to children with the lowest household SES (PP: 0.09 (95%CI: 0.07, 0.11) vs 0.19 (0.16, 0.21) and (PP: 0.07 (95%CI: 0.05, 0.09) vs 0.17 (0.13, 0.21) for highest vs lowest household SES in middle and high neighborhood SES, respectively). Hence, low-SES in either variable is enough to be associated with increased prevalence of obesity.

1. Introduction

Childhood obesity affects nearly 1 in 5 children between 6 and 11 years old in the United States (US) (Hales et al., 2018). Childhood is critical in the development of lifelong obesity because children who are overweight are more likely to become obese in adolescence and adulthood and suffer related adverse health outcomes (Dietz, 1994; Wisemandle et al., 2000).

It is widely recognized that the environment influences individuals' choices and hence the capacity to maintain a healthy body weight. Neighborhood socioeconomic status (SES) is one such environmental feature that has been consistently linked to both adult and childhood obesity (Finch et al., 2010; Greves Grow et al., 2010; Kimbro and Denney, 2013; Nau et al., 2015; Jones-Smith et al., 2014). The association between neighborhood deprivation and obesity persists after adjusting for individual factors including race/ethnicity and individual SES (Kimbro and Denney, 2013; Rossen, 2014; Powell et al., 2007). Neighborhood factors are hypothesized to influence childhood obesity outcomes through a variety of mechanisms, including through access to healthy foods, availability of places for exercise, and elevated chronic stress (Powell et al., 2007; Dallman et al., 2006). Because young children likely spend most of their time close to home, they may be influenced by their environment to a greater degree than older children or adults, both directly as well as indirectly through their parents' behaviors (Nau, 2015; Brooks-Gunn and Duncan, 1997; Singh et al., 2010).

Similarly, there is ample evidence of an association between household SES and childhood obesity (Ogden et al., 2018; Williams et al., 2018). While it is conceivable that neighborhood deprivation varies in its association with obesity outcomes depending on the level of

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household SES, very few studies have specifically examined this relationship. One study of eighth-grade students in Texas (Springer, et al., 2015) found that schools with higher poverty rates had a higher prevalence of obesity compared to schools with lower poverty rates, and, within them, students living in households with high SES were at an even higher risk compared to those students with lower household SES in these high poverty schools (Springer, et al., 2015). Students with low household SES who attended low poverty schools, experienced a lower prevalence of obesity compared to their counterparts attending high poverty schools. A second study also looked at this possible interaction utilizing the nationally representative National Health and Nutrition Examination Survey (NHANES) (Rossen, 2014). The authors found that, in children 2–18 years of age, higher household income was associated with lower prevalence of child obesity in low-poverty areas but was associated with higher probability of obesity in higher-poverty neighborhoods. Similar to the Texas study, the effect of neighborhood deprivation was more strongly associated with obesity outcomes for higher-income households compared to lower-income households.

Building on this small body of literature, the current study aimed to investigate whether the association of neighborhood SES and obesity varies according to household SES. We used a large nationally representative sample of US children who were all approximately the same age to account for potential heterogeneity effect associated to age.

2. Methods

2.1. Study population

We used the de-identified Early Childhood Longitudinal Study-Kindergarten Class of 2011 (ECLS-K:2011) public-use dataset. This is a US nationally representative prospective sample of kindergarten children formed in the fall of 2010. The children were sampled by the National Center for Education Statistics using a multi-stage cluster sampling design with counties or clusters of counties sampled first, then public and private schools within those counties, and then finally children within selected schools. Details of the sampling procedure and study design are available in the ECLS-K:2011 User's Manual (Najarian et al., 2018).

Our dataset corresponds to a cross-sectional sample of children who provided baseline kindergarten data and for whom sampling weights were estimated (N = 18,174) (Najarian et al., 2015) and were followed through the spring of their first-grade year in 2012 (N = 11,560). Most children lost to follow-up between kindergarten and first grade samples changed schools or left the country entirely. ECLS-K:2011 followed children who moved from a random sample of 50% of schools in order to reduce any bias from differential loss to follow-up. Once identified, children were approached in school by trained ECLS-K:2011 staff to complete a child assessment and parents were contacted for interview. Response rates for the first-grade year were over 85% for the child assessment and 76% for the parent interview. To assess the impact of the higher non-response rate for parents, ECLS-K:2011 compared estimates weighted by the nonresponse-adjusted weights with estimates weighted by only the base weights. They found non-significant differences and concluded that the potential for substantial nonresponse bias was unlikely (Najarian et al., 2015). For our analysis, we include children who were surveyed in the spring first grade assessment and who had complete information on our independent and dependent variables of interest and on covariates. After excluding children without follow-up information during their first-grade year (n = 3,042), BMI score (n = 68), poverty score (n = 1,373), urbanicity (n = 256), and race/ethnicity (n = 1), the final sample for this analysis was 9,862 children, 85% of the N = 11,560 children who were included in the first-grade sample.

2.2. Dependent variable

Our primary outcome of interest was obesity, which we defined based on body mass index (BMI) (weight (kg)/height (m^2)), which is considered a suitable proxy for adiposity in children (Poskitt, 2000). Height and weight were measured and recorded twice for accuracy in the spring of 2012 by trained ECLS-K:2011 staff utilizing a Shorr board and digital scale. Height was rounded to the nearest quarter inch and weight to the nearest tenth of a pound. The resulting BMI scores were then transformed into standardized measures using the *zanthro* package in Stata and the 2000 Centers for Disease Control and Prevention (CDC) growth reference charts, which take in account child's age and sex (Kuczmarski et al., 2002). We planned to exclude BMI scores greater than 8 standard deviations above or 5 standard deviations below the mean in either direction due to their likelihood of being implausible values; however, no BMI values exceeded these thresholds. The remaining standardized BMI scores were then categorized dichotomously based on their resulting BMI percentile as obese (≥95th percentile) or not obese. In sensitivity analyses, we converted BMI z-scores to their percent of the 95th percentile and examined this as a continuous outcome (Growth Chart Training).

2.3. Exposure

The main exposure of interest was neighborhood SES. It was measured as the percentage of all children 5–17 years of age in the child's school district living in a household below the federal poverty line. This value was obtained by ECLS-K:2011 directly from the Small Area Income and Poverty Estimates (SAIPE) administered by the United States Census Bureau in 2010 (US Census Bureau). The school district poverty values, provided as percentages in the dataset, were divided into tertiles for analysis and interpretation. The lowest tertile represented the lowest district poverty (i.e. higher SES neighborhood) while the highest tertile represented the highest district-poverty (i.e. lowest SES neighborhood). We refer to this variable as neighborhood SES for convenience so that is consistent with the label for household SES; however only one dimension of SES (percent of the population living in poverty) is represented in this measure.

2.4. Effect measure modifier

We were interested in whether household SES modified the association between neighborhood SES and obesity. Each child was assigned a household SES score, which was created by ECLS-K:2011 as a composite of parents' education, occupation, and household income, all of which were reported by parents during the parent interview (Najarian et al., 2015). The household SES score was standardized, ranging from −2.3 to 2.3. These household SES scores were reverse coded so that higher values indicate lower household SES and then divided into tertiles, consistent with the format and direction of the neighborhood SES variable.

2.5. Covariates

Potential confounders were identified using a directed acyclic graph (DAG) (Fleischer and Roux, 2008) (Supplementary Materials) to determine variables that were *a priori* hypothesized to influence both obesity and neighborhood SES. The minimally sufficient adjustment set included only household SES, and child's race/ethnicity. However, additionally adjusting for child's age, sex, and urbanicity did not pose problems (i.e. adjusting for a mediator or opening a back door path). Due to the fact that these variables are typically included for precision, we present our primary model with adjustment for child's race/ethnicity, age and sex. Age was calculated in months based on the child's date of birth provided by the school during time of sampling and then confirmed by parents in the spring kindergarten interview. Sex was also provided by the school and then confirmed by parents. Race/ethnicity of each child was ascertained through the kindergarten parent interview as one of eight mutually exclusive categories (non-Hispanic (NH) white, NH black, Hispanic, race specified, Hispanic, no race specified, NH Asian, NH Native Hawaiian or other Pacific Islander, NH Alaskan Native/American Indian, two or more races or race unknown). The urbanicity of each child's school district was obtained by ECLS-K:2011 from the 2009–2010 Private School Universe Survey for private schools and the 2010–2011 Common Core of Data for public schools and defined by the NCES (Kuczmarski et al., 2002).

2.6. Statistical analyses

The sample included only children with complete data in all variables, including covariates. Dummy variables were created for all nominal categorical variables and age was grand mean centered for meaningful interpretation. During model fitting, both standardized household and neighborhood SES continuous measures were also plotted against standardized continuous BMI scores to identify if there was a linear relationship. Non-parametric modeling using the Lowess smoothing method revealed non-linear trends between both household and neighborhood SES and the outcome, standardized BMI, and so both were modeled as tertiles to allow for greater flexibility in the model during analysis. The dichotomous outcome of being obese or non-obese was modeled using multivariable log-binomial regression (McNutt et al., 2003). This model allows us to interpret the exponentiated coefficients as prevalence ratios.

The overall number and prevalence for each categorical measure was tabulated and the mean and standard error of each continuous variable was determined for the dataset as well as across the three separate tertiles of neighborhood SES, our main exposure. The adjusted prevalence ratios of obesity were then estimated using the multivariable log-binomial regression model with interaction terms between all levels of neighborhood and household SES. All potential confounders were included in the final model; we conducted sensitivity analyses using a smaller set of confounders identified as the minimally sufficient set (one model with race/ethnicity only and one model with urbanicity only (in addition to household SES and neighborhood SES and their interaction)). A post-estimation adjusted F-test was used to test the joint significance of the interaction term to the model. Post-estimation linear combination using the *margins* command was then used to generate predicted probabilities of obesity for each sub-group of household and neighborhood SES combination. Sampling weights provided by ECLS-K:2011 and Taylor Series linearization methods using the *survey* package in Stata were used for all data analyses in order to estimate variances. This method was utilized as it accounts for the clustered, multistage sampling design, which is consistent with the sampling methodology of the ECLS-K:2011 and produces more conservative confidence intervals and thereby reducing the likelihood of type I errors. All statistical analyses were performed using Stata 14 (StataCorp., 2015).

2.7. Ethics statement

Data for this study came from the publicly available version of the ECLS-K:2011 sample, which is maintained by the National Center for Education Statistics. The University's IRB deemed the analysis of these data not Human Subjects Research and therefore exempt from IRB review.

3. Results

Table 1 summarizes weighted means for all variables, standard deviation (SD) for age, and percentages for all other covariates, by categories of neighborhood SES. The overall proportion of children who were overweight/obese was 15.3%, with the highest prevalence seen in lower SES neighborhoods. Similarly, the distribution of race/ethnicity, urbanicity, and household SES categories were different across neighborhood SES. Most children living in high SES neighborhoods were also living in high SES households (50% in the highest household SES tertile); similarly, most children living in low-SES neighborhood, also belonged to low-SES households (56%). The correlation between the continuous versions of neighborhood SES and household SES was 0.43 (data not shown). However, there were also children living in discordant situations with 19% from low-SES household living in high SES neighborhoods, and 13% living in low-SES neighborhoods but high-SES household. In addition, within high-SES neighborhoods we observed a higher concentration of non-Hispanic whites and children living in suburban areas compared to distributions in the lower SES neighborhoods. On the other hand, age and proportion of males was similar across neighborhood SES.

In models mutually adjusted for household SES and neighborhood SES as well as all covariates, the statistical interaction between household SES and neighborhood SES was statistically significant (p-value = 0.002), indicating that the association between neighborhood SES and obesity varied according to household SES (Table 2). For easier interpretation, we present the predicted probability of obesity for each combination of neighborhood and household SES tertiles (Fig. 1). For children in the lowest tertile of neighborhood SES, prevalence of obesity is not statistically significantly different comparing children with low, middle or high household SES (Predicted probability (PP): 0.20 (95% CI: 0.17, 0.23), 0.21 (95%CI: 0.18, 0.24), 0.16 (95%CI: 0.12, 0.20), respectively; Fig. 1). Conversely, within the highest and the middle tertile of neighborhood SES, children with high household SES have significantly lower prevalence of obesity compared to children with the lowest household SES in these neighborhoods (PP: 0.09 (95%CI: 0.07, 0.11) vs 0.19 (0.16, 0.21) and (PP: 0.07 (95%CI: 0.05, 0.09) vs 0.17 (0.13, 0.21) for highest vs lowest household SES in middle and high neighborhood SES, respectively). So, while having either low neighborhood or low household SES is associated with similarly increased prevalence of overweight and having high SES on one of these dimensions only does not mitigate the risk of having low SES on the other, having low SES on both dimensions is also not associated with multiplicatively increased risk. The difference in the predicted probability of obesity between children from the most advantaged backgrounds (high household SES and high neighborhood SES) to those with the least advantaged backgrounds (low household SES and low neighborhood SES), shows a large disparity with a 14 point difference in predicted probability (0.07 vs 0.20; Fig. 1). Results of sensitivity analyses using BMI expressed as percent of the 95th percentile of BMI for age and sex and those with a smaller set of confounding variables were substantively similar in terms of direction and significance (Supplemental Tables 1 & 2).

4. Discussion

Using a national sample of first-grade children, we found evidence that a child's household SES modifies the association between neighborhood SES and prevalence of overweight/obesity. Both SES variables, household and neighborhood SES, were associated with obesity. In particular, for children living in low SES neighborhoods, having high household SES was not associated with lower probability of obesity as compared to children with lower household SES in these neighborhoods. Second, we found no evidence that living in a high-SES neighborhood mitigates the negative association of having a low-SES household: the predicted probabilities for children with low-SES household across strata of neighborhood SES were similar. Third, we found no evidence of multiplicatively greater risk of obesity due to low-SES household and low neighborhood SES (*double jeopardy*): children from either low-SES households or neighborhoods had similar risk regardless of the level of SES of the other condition.

These findings are consistent with results from the NHANES where

Table 1
Sample characteristics for ECLSK:2011[1] study participants overall and by tertiles of neighborhood SES.[2]

	Total (N = 9,826)	High Neighborhood SES (N = 3,500) (2–13% in poverty)	Medium Neighborhood SES (N = 3,373) (14–25% in poverty)	Low Neighborhood SES (N = 2,953) (26–56% in poverty)
Age in months, Mean (SD)	85.5(0.1)	85.4 (0.2)	85.7 (0.2)	85.2(0.2)
Sex, N(%)				
Male	5,033(51.2)	1,790(51.1)	1,743(51.7)	1,500(50.8)
Female	4,793(48.8)	1,710(48.9)	1,630(48.3)	1,453(49.2)
Race/Ethnicity, N(%)				
Non-Hispanic white	4,819(49.0)	2,342(66.9)	1,659(49.2)	818(27.7)
Non-Hispanic black	1,036(10.5)	178(5.1)	257(7.6)	601(20.4)
Hispanic, race specified	2,432(24.8)	375(10.7)	846(25.1)	1,211(41.0)
Hispanic, no race specified	134(1.4)	21(0.6)	54(1.6)	59(2.0)
Asian, non-Hispanic	810(8.2)	357(10.2)	297(8.8)	156(5.3)
Native Hawaiian/other Pacific Islander, non-Hispanic	51(0.5)	18(0.5)	23(0.7)	10(0.3)
Alaskan Native/American Indian	76(0.8)	10(0.3)	49(1.5)	17(0.6)
Two or more races or race unknown	468(4.8)	199(5.7)	188(5.6)	81(2.7)
Urbanicity, N(%)				
Urban	3,065(31.2)	394(11.3)	1,089(32.3)	1,582(53.6)
Suburb	3,587(36.5)	1,982(56.6)	1,019(30.2)	586(19.8)
Town	826(8.4)	313(8.9)	423(12.5)	90(3.0)
Rural	2,348(23.9)	811(23.2)	842(25.0)	695(23.5)
Household SES, N(%)[3]				
High	3,086(31.4)	1,759(50.3)	946(28.0)	381(12.9)
Medium	3,322(33.8)	1,178(33.7)	1,221(36.2)	923(31.3)
Low	3,418(34.8)	653(18.7)	1,206(35.8)	1,649(55.8)
Obese, N(%)				
Non-obese N	8,352(84.7)	3,133(89.1)	2,879(85.3)	2,340(79.4)
Obese	1,474(15.3)	367(10.8)	494(14.6)	613(20.6)

[1] Early Childhood Longitudinal Study, Kindergarten Class of 2011; students were in first grade during our study observation period.

[2] Values are weighted means (Standard Deviations) for age and unweighted counts (weighted proportion) for sex, race, urbanicity, household SES, and overweight or obese variables.

[3] Household SES defined as tertiles of standardized SES scores with low SES as the lowest tertile (reverse coded standardized composite scores of 0.5–2.33), medium as the medium tertile (reverse coded standardized composite scores of −0.3, 0.49), and high as the highest tertile of SES((reverse coded standardized composite scores of −2.37, −0.31)).

it was found that neighborhood deprivation was significantly associated with a higher odds ratio of obesity among children above the poverty threshold (Rossen, 2014) but is different from what was found in the eighth-grade population in Texas where children in the lowest SES group who attended schools in less economically disadvantaged neighborhoods had a substantially decreased prevalence of obesity (Springer et al., 2015). While our results suggest that children with additional household SES resources still experience high risk for obesity if they have low neighborhood SES, differences might be explained by differences in context between the sample concentrated in Central Texas and our nationally representative sample, or in differences in the age of the two samples. For children from low-SES families, it is possible that the lack of socioeconomic resources in the household prohibited any beneficial effects of living in a high-SES neighborhood.

Our results support the finding of Rossen (2014) that children may not be at a higher risk of obesity if they are living in double jeopardy conditions as compared to having only one risk factor, as suggested by other authors (Pickett and Pearl, 2001; Morenoff and Lynch, 2004). Rossen also found that having high household SES is not protective against the additional risk associated with low neighborhood SES, consistent with our findings (Rossen, 2014). However, similar to the Texas study and dissimilar from our findings, within low SES neighborhoods, having high family SES is associated with relatively higher prevalence of obesity compared to lower family SES.

Overall, our findings suggest that the risk for obesity is high if the child is from either a low-SES household or neighborhood and the risk is similar regardless of the combination of the two once one of the high-risk conditions is met. Potential pathways have been previously explored in the literature. Living in a low-SES household is associated with higher probability of lower diet quality through lack of income (Brooks-Gunn and Duncan, 1997). Household poverty is associated with low fruit and vegetable consumption and overall lower quality diet because often least inexpensive foods are also more energy dense and less healthy (Drewnowski and Specter, 2004). Increased physical activity levels have also been repeatedly associated with higher socioeconomic status (Sobal and Stunkard, 1989). Low SES has also been associated with experiencing chronic stressors, which can lead to unhealthy diet or physical inactivity (Ng and Jeffery, 2003), poor sleep quality (Burgard and Ailshire, 2009), or to coping strategies like overeating (Adam and Epel, 2007) that ultimately negatively impact health outcomes (Baum et al., 1999).

Limitations of this study should be noted. First, our ability to infer causal relationships are limited due to the nature of our cross-sectional data. Specifically, temporality between the exposure of interest and outcome cannot be established and so it is possible parents' BMI, and therefore child BMI, may cause selection into neighborhoods rather than child BMI being a result of neighborhood characteristics. Second, there may be unmeasured or residual confounding that has not been accounted for in this analysis. Third, the data reflect associations among a limited demographic—children in first grade in 2012. While we think this relationship may change with age, and that future studies should investigate this, we also think that these relationships are likely slow to change over calendar year or period. Fourth, we rely on the poverty-level of the school district geography to represent a child's neighborhood-level poverty. Similar to many other geographic units, school district boundaries may not perfectly correspond to what children or parents consider to be their neighborhood and it is subject to the modifiable areal unit problem, meaning that the association between our exposure and outcome could change if we used a different geographic unit (Wong et al., 2004). An additional limitation of using school district boundaries to proxy neighborhood SES is that some children may attend a school that is not in their neighborhood school and this would result in misclassification of neighborhood SES if the school they attend falls into a different tertile of SES. Additionally, we

Table 2
Adjusted prevalence ratios (PR) from a log-binomial regression of the association between neighborhood SES with childhood obesity status, allowing for the association to vary by household socioeconomic status (SES) among ECLSK:2011.[1]

	PR (95% CI)	P-value
Neighborhood SES[2]		
High(ref)	Ref	
Medium	1.32 (0.98, 1.79)	0.07
Low	2.28 (1.63, 3.17)	< 0.01
Household SES[3]		
High(ref)	Ref	
Medium	1.91 (1.46, 2.50)	< 0.01
Low	2.40 (1.82, 3.15)	< 0.01
Interaction Terms[4]		
High household SES * High Neighborhood SES	Ref	
Medium household SES * Medium Neighborhood SES	0.76 (0.52, 1.12)	0.17
Medium household SES * Low Neighborhood SES	0.68 (0.47, 0.98)	0.04
Low household SES * Medium Neighborhood SES	0.83 (0.61, 1.13)	0.24
Low household SES * Low Neighborhood SES	0.51 (0.36, 0.72)	< 0.01
Age	1.00 (0.99, 1.01)	0.66
Sex		
Male(ref)	Ref	
Female	0.90 (0.80, 1.01)	0.08
Race		
Non-Hispanic white(ref)	Ref	
Non-Hispanic black	1.30 (1.07, 1.57)	< 0.01
Hispanic, race specified	1.46 (1.26, 1.70)	< 0.01
Hispanic, no race specified	1.00 (0.62, 1.60)	0.99
Asian, non-Hispanic	0.95 (0.70, 1.27)	0.71
Native Hawaiian/other Pacific Islander, non-Hispanic	1.73 (0.94, 3.16)	0.08
Alaskan Native/American Indian	2.26 (1.79, 2.86)	< 0.01
Two or more races or other race	1.37 (1.07, 1.75)	0.01
Urbanicity		
Urban(ref)	Ref	
Suburb	1.13 (0.97, 1.32)	0.12
Town	1.07 (0.78, 1.47)	0.66
Rural	1.26 (1.06, 1.49)	< 0.01

*p < 0.05.

[1] Early Childhood Longitudinal Study, Kindergarten Class of 2011; students were in first grade during our study observation period.

[2] Neighborhood SES defined as tertiles of % of children 5–17 years of age living in a household below the poverty line within in a school district. The highest tertile of neighborhood SES represents the lowest level of poverty.

[3] Household SES defined as tertiles of reverse coded standardized SES scores with low SES as the lowest tertile, medium as the medium tertile and high as the highest tertile of SES.

[4] Adjusted Wald Test for all interaction terms taken together was significant with p = 0.002.

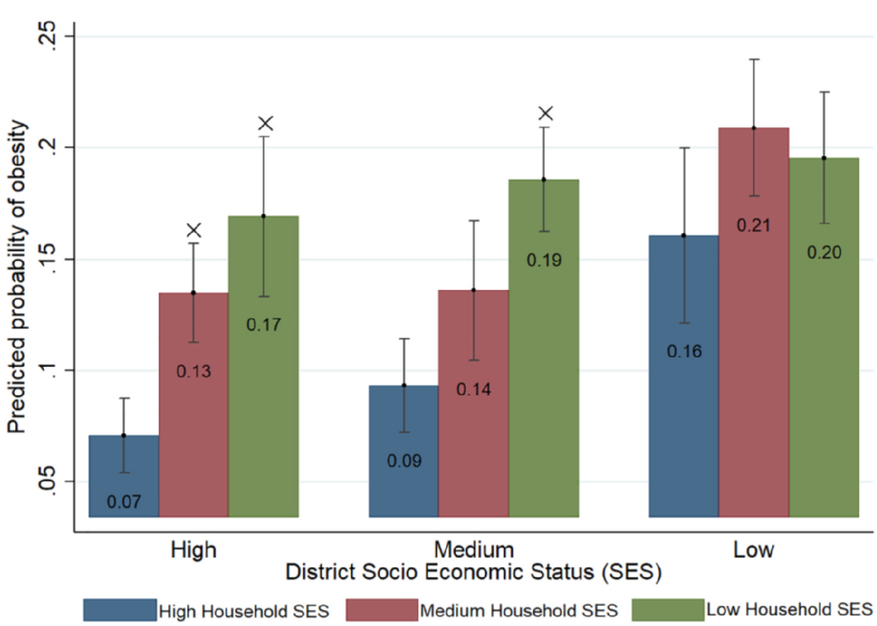

Fig. 1. Predicted probability of obesity by neighborhood SES and household SES from adjusted log-binomial regression models. The cross sign (X) Indicates, within each neighborhood SES strata, a significant relative risk ($p < 0.05$) of obesity compared to high neighborhood SES (the reference category). odels include the main effects for neighborhood SES and household SES, interaction terms between tertiles of neighborhood SES and household SES, child race/ethnicity, age, sex, and an indicator variable for urbanicity. Total sample size, N = 9826.

should note that our household SES measure is a composite measure that combines information about family income, both parents' education levels, and occupation, whereas our measure of neighborhood SES only measures one dimension of SES—percent of the population living in poverty. Finally, we include the covariate of race/ethnicity to be a proxy for differences in societal and interpersonal treatment and racism experienced based on socially constructed categories of race/ethnicity, which is an imperfect proxy for these exposures.

Despite these limitations, this study also has several strengths. The data come from a contemporary, large, nationally representative sample of children and therefore results are generalizable to the US population of first grade children. The values for height and weight were measured directly by trained staff. Measured values are preferable to parent-reported values due to their increased reliability (Himes, 2009). Finally, this study also captures children at a critical age for development of life-long overweight/obesity. Identifying the circumstances surrounding children at this age is essential when developing appropriate intervention strategies.

In conclusion, we found that low-SES in either household or neighborhood is enough to put children at higher risk of obesity than their peers from higher SES settings, and the interaction between them does not mitigate their impact or create a synergistic effect. Future studies should continue to explore this interaction in the context of longitudinal data to improve causal inference and investigate the mechanisms that are involved in this complex interaction.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2020.101207.

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