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A cross-sectional study of the influence of neighborhood environment on childhood overweight and obesity: Variation by age, gender, and environment characteristics

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ABSTRACT

To examine the influence of neighborhood environment on childhood overweight and obesity in Shelby County Schools, Tennessee, and whether and to what extent that influence varies by age, gender, and the specific environment characteristics. 41,283 students were surveyed covering both individual-level covariates and several objective measures of neighborhood environment. Multilevel logistic regressions were used to examine the influence of neighborhood-level variables on overweight + obesity and obesity with adjustment of individual-level covariates. Further, a stratified analysis for each of the six groups by school level and gender. For both overweight + obesity and obesity, younger children were less sensitive to neighborhood characteristics than older children, and boys are less sensitive than girls. For girls in middle and high schools, the risk of overweight + obesity and obesity were positively associated with population density, and negatively associated with percent of poverty and percent of unhealthy food. Boys' risk of overweight + obesity and obesity were positively associated with distance to park. Neighborhood environment plays an important role in childhood overweight and obesity, and the effects vary by age, gender, and the specific neighborhood characteristic. Intervention programs tailored to specific groups may be more effective than ones targeted to children as a whole.

1. Introduction

Childhood obesity is a major public health problem both nationally and internationally (Karnik and Kanekar, 2012; White House Task Force on Childhood Obesity, 2010). Recent data show that about 31.8% of children (2–19 years of age) are either overweight or with obesity (Ogden et al., 2014). Childhood obesity has multiple negative effects on health and wellbeing and the current generation may be the first generation in the past two centuries to have a shorter lifespan than their parents (Olshansky et al., 2005). Moreover, childhood obesity imposes substantial economic costs (Hammond and Levine, 2010). Childhood obesity is more prevalent among minority and groups of lower socioeconomic status (Wang and Beydoun, 2007; Chung et al., 2014), with significant disparities among geographic areas at both the neighborhood and the state levels (Wang and Beydoun, 2007).

The neighborhood environment may be conductive or prohibitive to physical activities and healthy diet that are associated with reduced incidence of overweight and obesity (Auchincloss et al., 2013; Black and Macinko, 2008). It has been reported that children living in neighborhoods with higher land use density, higher land use mix, less crime, higher traffic safety, and greater access to recreational facilities are more likely to be physically active and less likely to engage in sedentary indoor activities such as watching TV, surfing the Internet, and playing computer games (Hillier, 2008). Also, children living in neighborhoods abundant with fast food outlets and poor access to healthy foods are more likely to have unhealthy diets (Ohri-Vachaspati et al., 2013). Among the investigated environmental features, those found to be the most consistently associated with body mass index (BMI) are neighborhood socioeconomic status, walkability, access to recreational resources, and access to healthy foods (Carroll-Scott et al., 2013).

Overall the associations between neighborhood environment and childhood obesity have been established (Feng et al., 2010; Dunton et al., 2009; Lipek et al., 2015). However, our understanding is still limited in terms of the extent of a specific environment characteristics affects risk of overweight and obesity status among a specific group. One problem is that children are not a homogenous group, and the influence of neighborhood environment on childhood obesity may vary

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by individual characteristics including age and gender. For example, as children grow older, they are more autonomous, spend more time outside the house, and have more interactions with neighborhood environment (Aber et al., 1997). Consequently, the influence of neighborhood environment on childhood obesity may be more salient for older children (Alvarado, 2016). Likewise, the influence of neighborhood environment on obesity may be gender specific. Generally, boys are more physically active than girls (Telford et al., 2016). Living in neighborhoods with low safety or poor built-environment, girls are more likely to stay indoors, which may lead to decreased physical activity and obesity (Nogueira et al., 2013). Also, girls may be more sensitive to the food environment because emotional eating under stress is more prevalent among females than males (Vicennati et al., 2009). Finally, boys and girls may react differently to a specific environmental characteristic. For example, among the recreational facilities in the neighborhood, parks were found to be more important to boys, and commercial facilities were more important to girls (Sallis, 1993). Another example is that street intersection density (i.e., the ratio of the street intersections in an area) was found to be negatively related to obesity or overweight for Canadian girls, but not for boys (Spence et al., 2008). One study (Singh et al., 2010) using 2007 National Survey of Children' Health data found living in neighborhood with unfavorable conditions was associated with higher risk of with obesity or overweight and the effects were greater for female and children aged 10–11. Another recent study (Alvarado, 2016) using US national level data found that a disadvantaged neighborhood environment influences obesity more for adolescents than for younger children and more for girls than boys.

Another problem is the measurement of neighborhood environment. As Swinburn et al. (Swinburn et al., 1999) pointed out the general concept of neighborhood environment is nebulous, and we need to dissect it into concrete elements to be amenable to both measure and policy intervention. A specific neighborhood environment characteristic's influence on childhood obesity may vary by the specific group (e.g., age and gender) or the specific behaviors (e.g., physical activity and diet). Ideally, neighborhood environment should be measured from physical (or built), economic, socio-cultural, and political dimensions. For the economic dimension, the percent of poverty is one of the most common measures. For built (or physical) environment, the common measures include population density, land-use mix, access to recreational facilities, and street pattern (Brownson et al., 2009). One particular issue related with the built environment characteristics is that they could be measured both subjectively and objectively. Commonly, subjective measures were self-reported perceptions of environment (Nogueira et al., 2013) while objective measures were directly collected in the field or were obtained by computation on existing land use dataset (Sharifi et al., 2016). Discrepancies were reported between subjective and objective measures of the neighborhoods' environmental characteristics (van Lenthe and Kamphuis, 2011; Ball et al., 2008). It may be plausible that objective measures of neighborhood environment influence children's risk of obesity both directly and indirectly (through perception which may be modified by individual's properties) (Ball et al., 2008).

The aim of this study is to examine the influence of neighborhood environment on childhood overweight and obesity in Shelby County Schools, Tennessee using objective measures on both BMI and neighborhood environment. Particularly, we examined whether and to what extent the influence of neighborhood environment varies by age and gender.

2. Methods

2.1. Study population

The study population was identified from the children enrolled in Shelby County Schools (SCS), Tennessee's largest school district covering the city of Memphis (TN) and unincorporated areas of Shelby County. SCS is an urban school district with a student population of 111,500 that is 75.7% African American, 14.2% Hispanic; 10% Caucasian; and 2.1% Asian. Data were obtained from a state-mandated screening conducted by Coordinated School Health staff of SCS during the 2014–2015 academic year, which covers all students in Pre-K, K, 2, 4, 6, 8, and 9 grades. Out of about 46,000 eligible students, 41,432 had complete height, weight, and neighborhood-level data. In addition, 147 students were excluded because they lived outside the school district, and two excluded because they were > 18 years old, leaving a sample of 41,283 students (90%) in the study. For each student, the information included age, grade, gender, race, economically disadvantaged status (yes/no, determined by a student's eligibility for the free or reduced lunch program), school type, and residence zip code. Schools were categorized as public schools, charter schools, and alternative schools (i.e., those serving students who are experiencing academic as well as behavioral challenges in the traditional school setting). Also, schools were categorized into three levels: elementary, middle, and high schools. The study outcomes were overweight + obesity (defined as the ≥ 85th percentile) and obesity (defined as the ≥ 95th percentile) as computed from CDC's Growth Charts (CDC, 2017).

2.2. Neighborhood-level variables

Residence zip codes were used as proxies of neighborhoods. Table 1 shows detailed information for the six neighborhood-level variables used in this study. The population density and the percentage of the population below poverty level for each zip code were obtained from

Table 1
Neighborhood-level environmental variables.

Name	Description and unit	Mean and range among zip codes	Data source
Population density	# of people/area; thousand persons per mile^2	2.43, [0.01, 4.65]	American Community Survey (2007–2011)
Percent of poverty	Percent of people below poverty level, %	18.9, [2–61]	American Community Survey (2007–2011)
Intersection density	# of intersections/area; # per mile^2	125.5, [32.1–252.8]	ESRI data DVD (2008)
Walk score	A walkability index based on the distance to the closest amenity in a number of categories; walk score ranges between 0 and 100, with a higher number indicating higher walkability.	30.9, [0–91]	Online (2013)
Distance to park	With population size as weights, the distance to the nearest park was calculated for each census block, then aggregated to zip code level; mile	16.4, [0.018–38.1]	ESRI data DVD (2008)
Percent of unhealthy food[a]	The percentage of unhealthy food retailers among the total number of all food retailers, %	85.3, [50,100]	US census zip code business patterns (2013)

[a] According to CDC (CDC, 2011), healthy food retailers include supermarkets, supercenters, and produce stores, and less healthy food retailers include convenience stores, fast food restaurants, and small grocery stores with 3 or fewer employees.

the 2010–2014 American Community Survey (ACS) data (U.S. Census Bureau, 2017). For built environment, we employed four variables that have been previously shown to be associated with residents' obesity. These included density of street intersections (a measure of the street connectivity); walk score (a measure of walkability) (Carr et al., 2010; Duncan et al., 2011); population-weighted distance to the nearest park (a measure of accessibility to recreational facilities); and percent of unhealthy food (the number of unhealthy food retailers to the total number of all food retailers, a measure of food environment) (Xu et al., 2015). The first three variables were constructed using multiple data sources ranged between the year of 2010 and 2016, with detailed information available elsewhere (Xu et al., 2015). The percent of unhealthy food was calculated using 2013 US Census Zip Code Business Patterns data (US Census Bureau, 2017). Unhealthy food retailers include convenience stores, fast food restaurants, and small grocery stores with 3 or fewer employees (CDC, 2011).

2.3. Statistical analysis

The demographic characteristics of the study population were summarized. Multilevel modeling has been widely applied to the study of neighborhood and health outcomes including obesity (Xu et al., 2015; Zhang et al., 2013) because it allows for the simultaneous estimation of the effects of individual-level and group-level factors, adjusting for non-independence of observations within the group. The data had a clustered structure with students nested within the neighborhood, that is, the students living in the same neighborhood share the same environmental exposures. We used multilevel logistic regression models to examine the influence of neighborhood-level variables on childhood obesity with adjustment of individual-level covariates including age, gender, race, economically disadvantaged status, school type, and school level. Two levels of excessive weight were examined including (Karnik and Kanekar, 2012) overweight + obesity (≥ 85 percentile), and (White House Task Force on Childhood Obesity, 2010) obesity (≥ 95 percentile). Further, we conducted a stratified analysis for each of the six subgroups of school level (i.e., elementary, middle and high schools, as a proxy of age groups) by gender. SAS PROC GLIMMIX was used for the logistic regression. All the analysis was conducted using SAS 9.4 (Cary, NC).

3. Results

Overall, 16.0% of the students were overweight and 22.6% were with obesity. The descriptive characteristics of the study population are shown in Table 2. The average age was 9.6 years, with minimum 3 years and maximum 18 years. The mean ages were 7.0, 12.3, and 14.5 years for students in elementary, middle, and high schools, respectively. The majority of the students (76.4%) were blacks, followed by Hispanics (13.7%), whites (7.2%), and Asians (1.7%). Fifty one percent were girls. The majority of students (82.2%) were classified as economically disadvantaged. Most students (91.4%) were in public schools, 7.4% were in Charter school, and only 1.2% were in alternative schools. The prevalence of overweight and obesity is significantly different by basic demographic characteristics, except for the economically disadvantaged status (Table 2). The prevalence of overweight and obesity were much higher among Hispanic children than other races/ethnicities.

Fig. 1 shows the spatial distribution of overweight + obesity and obesity in Shelby County Schools district at the zip code level. Overall, overweight + obesity and obesity have similar patterns: the zip codes with relatively lower prevalence form three clusters in the north (i.e., 38,053 and 38,002), downtown/midtown (around 38,104), and Eastern Memphis areas (around 38,120 and 38,138).

Table 3 presents the adjusted odds ratios of overweight + obesity and obesity among students (3–18 years old). Risk of overweight + obesity (OR = 1.05, 95% CI = 1.04, 1.06), and obesity (OR = 1.04; 95% CI = 1.03, 1.05), increased with age. Girls were at higher risk of overweight + obesity (OR = 1.12, 95% CI = 1.08, 1.17), and obesity (OR = 1.06, 95% CI = 1.01, 1.11), than boys. Economically-disadvantaged status had no significant influence on weight. Compared to Whites, Hispanic children were at higher risks for overweight + obesity (OR = 1.73, 95% CI = 1.57, 1.92) and obesity (OR = 1.82, 95% CI = 1.62, 2.06). Secondary to Hispanic, the ORs for Black were 1.15 (95% CI = 1.06, 1.26) and 1.24 (95% CI = 1.11, 1.38) respectively. Students from alternative schools were with lower risk for overweight + obesity (OR = 0.77, 95% CI = 0.63, 0.94) and obesity (OR = 0.66, 95% CI = 0.52, 0.85) than students from public schools.

The influence of neighborhood-level variables on overweight + obesity is similar to their influence on obesity. The risk of overweight + obesity was inversely associated with population density (OR = 0.93, 95% CI = 0.88, 0.99), and positively associated with percent of poverty (OR = 1.01, 95% CI = 1.00, 1.01), distance to park (OR = 1.01, 95% CI = 1.00, 1.01), and percent of unhealthy food (OR = 1.01, 95% CI = 1.00, 1.01). The association of intersection density with childhood overweight + obesity was weak (OR = 1.00) and the association of walk score was not statistically significant ($P > 0.1$).

Table 4 shows the effects of the six neighborhood-level variables on overweight + obesity for all the six age/gender subgroups. Overall, boys' risk of overweight + obesity were less sensitive to environmental variables than girls', and children in elementary schools were less sensitive to environmental variables than children in middle or high schools. The risk of overweight + obesity for girls in middle and high schools was inversely associated with population density (OR = 0.87, 95% CI = 0.77, 0.98, and OR = 0.86, 95% CI = 0.75, 1.00, for girls in middle and high schools, respectively), and positively associated with percent of poverty (OR = 1.01, 95% CI = 1.00, 1.02, and OR = 1.01, 95% CI = 1.01, 1.02, for girls in middle and high schools, respectively), and percent of unhealthy food (OR = 1.01, 95% CI = 1.00, 1.02, and OR = 1.01, 95% CI = 1.00, 1.03, for girls in middle and high schools, respectively). Boys in all levels were not sensitive to most environmental variables except for the distance to parks, which was stronger for older boys (ORs were 1.01, 1.01, and 1.01 for boys in elementary, middle, and high schools, respectively). Similar, but lesser, effects were observed for obesity alone (data are not shown).

4. Discussions

The prevalence of overweight + obesity (38.6%) and obesity (22.6%) among the students in Shelby County, TN were higher than US national level. For example, the obesity prevalence was 19.5% in elementary schools compared with US national level of 17.5% among 6–11 years old, and the obesity prevalence were Middle and high 23.3% in middle schools and 21.4% in high schools compared with US national level of 20.5 among 12–19 years old (Ogden et al., 2016). Our study examined both individual-level and neighborhood-level variables associated with overweight/obesity and obesity among children. Our results confirmed that the neighborhood-level characteristics' influence on childhood overweight and obesity, more important, the influence varies by age, gender, and the specific neighborhood characteristic.

Consistent with previous studies (Alvarado, 2016; Singh et al., 2010), overweight and obesity among younger children (students in elementary schools) were not associated with most neighborhood variables, most likely because younger children spend more time indoors than older children. Among middle and high schools students, girls' risk of overweight and obesity was associated with most neighborhood variables; but this did not hold true for boys. This is consistent with earlier findings (McDonald et al., 2012). This gender difference may be due to boys are more physically active than girls, regardless of neighborhood characteristics. Older girls are particularly sensitive to population density, percent of poverty and unhealthy food environment. Specific to the local context, population density may be

Table 2
Descriptive characteristics of the study population.

		Percent	Prevalence		
			Normal (> 5 and < 85 percentile)	Overweight (> 85 and < 95 percentile)	Obesity (> 95 percentile)
Gender	Male	49.1	60.8	15.1*	22.1*
	Female (ref)	50.9	58.0	16.9	23.2
Economically disadvantaged status	Yes	82.2	59.3	16.0	22.8*
	No (ref)	17.8	59.9	16.0	21.9
Race/ethnicity	Black	76.4	60.4	15.8*	22.0*
	Hispanic	13.7	50.8	17.9*	29.5*
	White (ref)	7.2	63.4	15.5	18.0
	Asian	1.7	66.4	14.5*	16.0*
	Others	1.1	63.2	15.0	20.1
School level	Elementary (average age: 7.0 years old)	57.4	61.4	15.0*	21.3*
	Middle (average age: 12.3 years old, as ref)	28.5	56.5	16.7	25.1
	High (average age: 14.5 years old)	14.1	57.2	18.8*	23.0
School type	Charter	7.4	55.7	16.6*	26.1*
	Public (ref)	91.4	59.7	16.0	22.4
	Alternative	1.2	61.9	18.1*	18.1*

Note: *P* value of the difference among groups comparing with the reference group on the prevalence of normal weight (≥ 5 and < 85 percentile): * < 0.05.

associated with certain demographical characteristics that are related to the risk of overweight + obesity or obesity. In the context of Shelby County, a higher population density may be associated with a higher level of land use mix that may promote girls' outdoor physical activities. In most US urban areas, a higher percent of poverty indicates lower safety and higher crime levels (Ludwig et al., 2001), thus, decreasing the opportunities for girls to engage in outdoor physical activities. Also, the risk of overweight and percent of unhealthy food only existed among older girls but not among older boys. This may be explained by females' emotional eating under stress, as mentioned in the introduction section (Vicennati et al., 2009). Our study indicated that boys' risk of overweight and obesity were associated with distance to park but not girls. This may conflict with several studies that found an association of park access and physical activities that are equal, or even stronger, in girls than in boys (Cohen et al., 2006; Fan and Jin, 2014). This discrepancy may be due to differences in measuring access to parks across the studies, as Wolch et al. (2011) have shown that parks' influence on children's BMI was significant when only considering the parks within 500 m distance from children's home.

One strength of this study is the use of multiple objective measures to describe the neighborhood environment. Among the four built environment variables used in this study, walk score and intersection density could capture neighborhood environment's influence on walking and other physical activities, distance to park may capture the influence on recreational activities, while percent of unhealthy food may capture the influence on diet. Although two previous studies (Alvarado, 2016; Singh et al., 2010) reported similar results, our study contributed uniquely to the study of neighborhood environment effect on childhood obesity. Unlike Alvarado's study, which used a single composite variable to describe the neighborhood disadvantage, our study report the individual effects of multiple neighborhood characteristics on children obesity providing, therefore, more direct evidence for policy intervention. The neighborhood variables used in Singh's study (Singh et al., 2010) were subjective measures obtained through the participants' questionnaires, and this may add more bias because the questionnaires were filled by parents instead of children themselves.

For individual-level characteristics, our results were consistent with most existing research (Ogden et al., 2016; Wang, 2011) that Black and Hispanic children were with higher risks for both overweight and obesity than other race/ethnicity groups, and girls were in higher risks in comparison to boys. Unlike other studies (Wang and Beydoun, 2007; Chung et al., 2014), we did not find an association of economically disadvantaged status with either overweight + obesity or obesity. This maybe because the majority of students in our study are from low-income households.

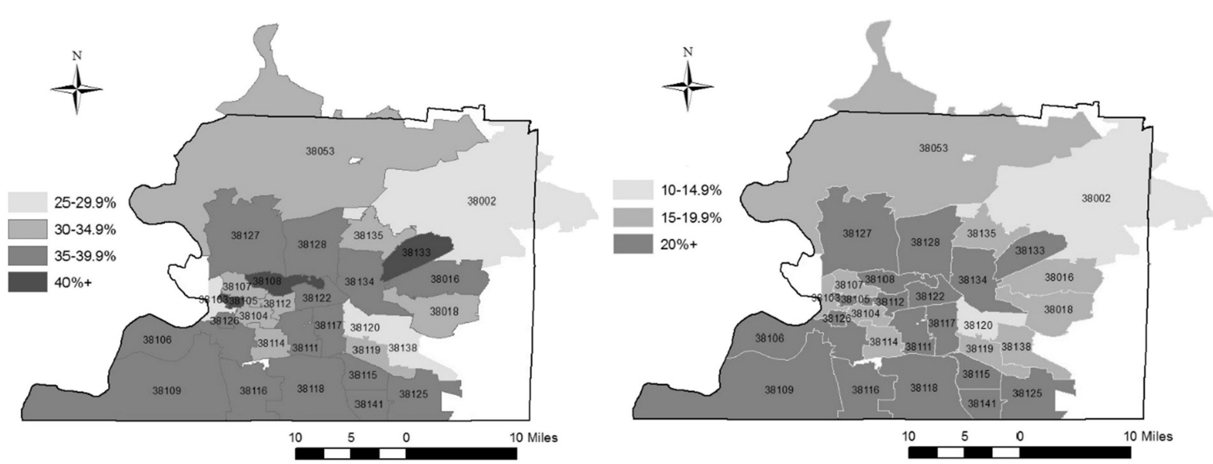

Fig. 1. Prevalence of overweight + obesity (left) and obesity (right) among students in Shelby County Schools district, at the zip code level.
Note: the black line is the boundary of Shelby County.

Table 3
Adjusted odds ratios for the association between overweight + obesity and individual-level and neighborhood-level variables among Shelby County Schools district student 2014–2015 (N = 41,283).

	Overweight + obesity (95% CI)	Obesity (95% CI)
Individual-level variables		
Age	1.05 (1.04, 1.06)***	1.04 (1.03,1.05)***
Gender (male as ref)	1.12 (1.08, 1.17)***	1.06 (1.01, 1.11)**
Economically disadvantaged (disadvantaged as ref)	1.00 (0.95, 1.06)	1.00 (0.94, 1.07)
Race (white as ref)	Overall *P* value***	Overall *P* value***
Black	1.15 (1.06,1.26)	1.24 (1.11,1.38)
Asian	0.85 (0.70, 1.02)	0.87 (0.69, 1.10)
Hispanic	1.73 (1.57, 1.92)	1.82 (1.62, 2.06)
Others	1.04 (0.84, 1.29)	1.12 (0.86, 1.46)
School (public as ref)	Overall *P* value**	Overall *P* value***
Charter	1.11 (1.02, 1.20)	1.13 (1.03, 1.24)
Alternative	0.77 (0.63, 0.94)	0.66 (0.52, 0.85)
Neighborhood-level variables[a]		
Population density	0.93 (0.88,0.99)**	0.95 (0.90, 1.01)*
Percent of poverty	1.01 (1.00,1.01)**	1.01 (1.00, 1.01)**
Intersection density	1.00 (1.00,1.00)*	1.00 (1.00, 1.00)
Walk score	1.00 (1.00,1.00)	1.00 (1.00, 1.00)
Distance to park	1.01 (1.00,1.01)**	1.01 (1.00, 1.01)**
Percent of unhealthy food	1.01 (1.00,1.01)**	1.00 (1.00, 1.01)

[a] See Table 1 for detailed information for each neighborhood-level variables.
* < 0.1.
** < 0.05.
*** < 0.0001.

An interesting result was that the risks of overweight + obesity were slightly higher for students in charter schools while much lower for students in alternative schools, as compared to students in public schools. One possible explanation is that although students in alternative schools have behavioral problems, they may tend to be more physically active. For example, it has suspected that violence may be connected with childhood obesity in various pathways (Midei and Matthews, 2011).

Our study highlighted the importance school-based screening data and will help to improve variables covered in the screening survey. The objective measurements of weights and heights overcome the bias from the self-reported survey. The large sample size (N = 41,283), allowed us to conduct stratified analyses to explore how the association between neighborhood environment and childhood overweight and obesity varies by age and gender, and create preliminary maps to illustrate the spatial pattern of overweight + obesity and obesity across the city of Memphis and Shelby County. With improvement, the school-based screening data may be applied to a more localized analysis. For example, if the household address could be provided at the level of census tract, census block group, or census block, we could conduct more advanced spatial analysis at a finer scale than our results in Fig. 1, and outcomes may enable us to pinpoint the small areas where children at greatest risk for overweight + obesity or obesity. Also, important variables, such as distance to parks, can be measured on the individual level. School-based screening could provide actionable information for evidence-based intervention programs promoting physical activity and healthy diet (Burns et al., 2017; Ritchie et al., 2015).

The study has some limitations. First, the absence of important demographic information including household socioeconomic status (Wang and Beydoun, 2007; Chung et al., 2014). Second, the household address was provided at the zip code level, and a zip code may not be a perfect proxy of the neighborhood. Smaller neighborhood proxies such as census tract or census block group or buffer zones around children's households may be better for such studies. However, the fundamental problem is that to study the influence neighborhood environment, the size of the neighborhood may vary by the specific health behavior, interested environmental variable, and children's subgroup. For example, it is plausible that an older boy could travel much further distance to buy some snacks than a younger girl could walk to a park for play. Third, the screening data were not from a survey with sampling design to be an unbiased representative of the children in SCS. Children who attended private school or did not attend any schools were not sampled. Similar to other cross-sectional and observational studies, our study could not determine any causal relationships and suffer from the "endogeneity" issue for studies on contextual effects (Kim et al., 2011).

This study may provide implications for the design of neighbor-level policy interventions to decrease childhood overweight and obesity in the US. Although our study is limited to the Shelby County of Tennessee, the conclusions may be generalizable to other metropolitan areas with higher prevalence of poverty and minority population. Improvement of the built and social environment of a neighborhood may directly promote healthy lifestyles such as healthy eating and active living behaviors among children. More important, as our result indicates, intervention program tailored to specific age group and gender may be more effective than ones targeted to children and adolescents as a whole. Also, considering the higher prevalence of overweight and obesity among girls, Hispanic, and Black, gender or race/ethnicity-oriented efforts may be promoted to decrease the health disparity. As our results show, girls are more sensitive to the neighborhood environment; creative programs may be needed to address this. For example, in neighborhoods with adverse environmental conditions and little chance of rapid improvement, indoor recreational facilities will be crucial for girls' to enhance physical activity.

Clinical trial registration

Not applicable.

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Table 4
Adjusted odds ratios (95% CI) for the association between overweight + obesity and neighborhood-level environmental variables among Shelby County Schools district student 2014–2015 stratified by gender and school level.

	Boys			Girls		
	Elementary (N = 12,016)	Middle (N = 6028)	High (N = 2972)	Elementary (N = 11,688)	Middle (N = 5727)	High (N = 2852)
Population density	0.98 (0.90, 1.06)	0.92 (0.80, 1.05)	1.00 (0.85, 1.16)	0.99 (0.91,1.09)	0.87 (0.77, 0.98)**	0.86 (0.75, 1.00)**
Percent of poverty	1.00 (1.00, 1.01)	1.00 (0.99, 1.01)	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	1.01 (1.00, 1.02)**	1.01 (1.01, 1.02)***
Intersection density	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.01)	1.00 (1.00, 1.01) *
Walk score	1.00 (1.00, 1.01)	1.01 (1.00, 1.01)*	1.00 (0.99, 1.01)	1.00 (1.00, 1.00)	1.00 (1.00, 1.01)*	1.00 (1.00, 1.01)
Distance to park	1.01 (1.00, 1.01)**	1.01 (1.00, 1.02)*	1.01 (1.00, 1.03)**	1.00 (0.99,1.01)	1.01 (1.00, 1.02)	1.01 (1.00, 1.02)*
Percent of unhealthy food	1.00 (1.00, 1.01)	1.01 (0.99, 1.02)	1.00 (0.99, 1.02)	1.00 (1.00, 1.01)	1.01 (1.00, 1.02)**	1.01 (1.00, 1.03)**

* < 0.1
** < 0.05.
*** < 0.0001.

Consortium.

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No financial disclosures were reported by the authors of this paper.

Author contributions

YY originated the study, conducted data analysis, and drafted the manuscript. YJ helped on data analysis. XY helped on neighborhood environment data preparation. ML helped to access the children obesity data. All authors provided feedback on research questions and helped to interpret the results and draft the manuscript. All authors read and approved the manuscript.

Transparency document

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