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ORIGINAL PAPER

The Association Between Obesity, Socio-Economic Status, and Neighborhood Environment: A Multi-Level Analysis of Spokane Public Schools

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Abstract
Socio economic inequities in obesity have been attributed to individuals' psychosocial and behavioral characteristics. School environment, where children spend a large part of their day, may play an important role in shaping their health. This study aims to assess whether prevalence of overweight and obesity among elementary school students was associated with the school's social and built environments. Analyses were based on 28 public elementary schools serving a total of 10,327 children in the city of Spokane, Washington. Schools were classified by percentage of students eligible for free and reduced meals (FRM). Crime rates, density of arterial roads, healthy food access, and walkability were computed in a one-mile walking catchment around schools to characterize their surrounding neighborhood. In the unadjusted multilevel logistic regression analyses, age, sex, percentage of students eligible for FRM, crime, walkability, and arterial road exposure were individually associated with the odds of being overweight or obese. In the adjusted model, the odds of being overweight or obese were higher with age, being male, and percentage of students eligible for FRM. The results call for policies and programs to improve the school environment, students' health, and safety conditions near schools.

Keywords School environment · Obesity · Socioeconomic status · Health equity

Background

Childhood obesity is associated with greater likelihood of remaining obese into adulthood and elevated risks of developing chronic diseases and disabilities earlier in life [1–3]. Analyses of data from 2015 to 2016 by the Centers for Disease Control and Prevention estimate that 18.5% of children in the United States are obese, defined as having body mass index (BMI) at or above the 95th percentile for their age. Although rates of obese children have leveled off or declined among some socioeconomic groups, stark socio-economic inequalities in obesity persist. For example, children from the lowest-income households are nearly twice as likely to be obese compared to children from the highest-income households.

Socioeconomic inequalities in obesity have been attributed to individuals' psychosocial and behavioral characteristics [4]. However, poor health outcomes are shaped not only by individual factors, but also by structural factors, like the social and physical environments of neighborhoods in which people live [5, 6]. Several studies have shown that the characteristics of a neighborhood can have a direct impact on individual health outcomes [7–9].

Children may be particularly vulnerable to poor social and environmental neighborhood conditions, as their mobility beyond the neighborhood tends to be limited compared to adults [10]. Additionally, the impact of these issues on their health and social functioning can last well into adulthood. For example, a recent longitudinal study found that access to supermarkets, fruit-and-vegetable stores, and recreational facilities was associated with less weight gain over 11 years [8]. Another study found that greater street connectivity, a measure of neighborhood walkability, was associated with lower BMI [9].

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The school environment, where children spend a large part of their day, can also play an important role in shaping children's health [11]. Moreover, because children often attend school within their neighborhoods of residence, public schools tend to be socially stratified, meaning that children of similar socioeconomic status (SES) often attend the same schools [12]. Previous studies have shown that factors like safety and traffic play an important role in parents' decisions concerning walking to school [13]. Parental safety concerns such as travel distance, traffic, and crime, have been associated with inactive commuting [13–15]. One report calculated that perceived traffic-related dangers presented barriers to walking and biking to school for 20 million children in the U.S. [16].

Using multi-level modeling, this study aimed to assess whether BMI levels in students from public elementary schools in Spokane, WA, were associated with the percentage of students eligible for free or reduced-price lunch and the built and social environments around their schools.

Methods

This study was conducted in the city of Spokane, the second-largest city in Washington State. Situated in Eastern Washington, Spokane is a mid-size city with a population of approximately 220,000 [17], serving as a hub for the surrounding rural areas in the state, as well as for northern Idaho and western Montana. Despite its central role within the region, the city's poverty rate is higher than the state average [17]. The city's median household income was $44,300 in 2015, with 18.3% of its population living below the poverty line [17]. By comparison, the household income for the state as a whole was $64,000, with 12.2% living below the poverty line [17]. In terms of school poverty, one-third of Spokane's elementary schools have rates of free and reduced meals over 80% [18].

The Washington State University Office of Research Assurances determined that this study satisfied the criteria for Exempt Research.

Participants

Students' age, sex, height, and weight measurements were obtained from the Spokane Public School District (SPSD). The SPSD annually collects data on elementary school students, grades K-6. Data for 21,395 students attending 31 elementary schools was received.

Procedure

Outcome Variable

Student records were excluded when school enrollment was based on a lottery rather than on geographical catchment (n = 737) and for those students with missing values on height, weight, or both measures (n = 1693). In addition, some students had duplicate measurements in which we excluded the duplicate measuremets (n = 8638). A continuous BMI measure for each student was calculated using their height and weight. Microsoft excel spreadsheets containing data files representing different growth curves (weight-for-age; stature-for-age; and BMI-for-age) for children, 2 to 20 years old, were obtained from the Centers for Disease Control and Prevention's website [19, 20]. Continuous BMI measures and growth curves were used to generate exact BMI percentiles and z-scores by sex and age for each student. Observations containing extreme values, as recommended by the Centers for Disease Control and Prevention, were flagged as being biologically implausible and excluded from the analysis (n = 133) [21]. The final sample consisted of 10,327 students from 28 schools. The outcome variable was dichotomous: (a) students who were underweight (less than the 5th percentile) or had normal weight (5th percentile to less than the 85th percentile); and (b) those who were overweight (85th to less than the 95th percentile) or obese (95th percentile or greater) [22].

Explanatory Variable

The addresses of elementary schools and percentage of students eligible for free and reduced meal (FRM) for 2017 were obtained from the website for Washington State's Office of the Superintendent of Public Instruction (OSPI) [18]. The percentage of students eligible for FRM were used as a proxy for a school's SES.

This analysis focused on the environmental and social conditions in neighborhoods within a one-mile walking (1.6 km) catchment surrounding each school. Road network data from the City of Spokane, together with the Network Analyst function within ArcGIS, was used to create a one-mile walking catchment around schools. Within each catchment, the following variables were calculated: crime counts for 2015 (continuous); exposure to arterial roads, a proxy for exposure to air and noise pollution (continuous); healthiness of the food environment, based on the modified Retail Food Environment Index [23] (continuous); and a walkability score based on the method developed by Frank et al. (continuous) [24]. Data on food establishments present in Spokane County, Washington, in 2017 were obtained from InfoUSA [25]. All other data sets were obtained from the City of Spokane [26]. All spatial analysis in this study was conducted using ESRI ArcGIS software version 5.1 [27]. The addresses of schools in this study were geocoded and mapped using Google Maps [28].

Several spatial analysis methods were used to prepare the data prior to analysis. The spatial join function was used to calculate crime rates and the percentage of healthy food establishments within each school catchment. Exposure to arterial roads was determined by creating a 100 m buffer around each arterial road and calculating the percentage of buffers intersecting the catchment area for each school. A buffer size of 100 m was used, as it has been shown in other studies to act as a proxy for both air and noise pollution exposure [29, 30]. A similar method was utilized to calculate the land use mix (i.e., the percentage of commercial, residential, and office land use) within each catchment and to calculate the walkability score for each one-mile walking catchment [24].

Data Analysis

Univariate statistics included descriptive statistics with measures of central tendency and variability for continuous variables as well as frequency distributions and percentages for categorical variables. Multilevel modeling was performed to examine the association between being overweight or obese with age, sex, percent of students eligible for FRM, and each school catchment characteristic, where students were clustered within those school catchments. The generalized linear mixed models procedure was used. A dichotomous variable (underweight or normal versus overweight or obese) was specified as the outcome variable in the regression models. Correlations within-school among students enrolled were accounted for using a random intercept model. A variance component matrix was specified. The Akaike information criterion (AIC) was used to test the goodness-of-fit of each model, with a lower value representing a closer model fit. The associations between outcome and explanatory variables were reported as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Variation was examined through the intraclass correlation coefficient (ICC). The data was analyzed using SPSS, version 25. The significance level was set at 0.05 (two-tailed).

Results

The study population consisted of 10,327 children in 28 schools. Data was summarized for three groups by percent of students eligible for FRM in schools ($\leq 50\%$, 51–74%, and $\geq 75\%$). Table 1 shows school and catchment characteristics by percentage of students eligible for FRM. Schools with more students eligible for FRM tended to have a lower percentage of non-Hispanic Whites, a higher percentage of racial minorities, and a higher percentage of children in special education. Some environmental and social aspects of the catchment around schools varied across the three FRM groups. The median residential property value around schools with more students eligible for FRM was $106,517, while that same value around schools with fewer students eligible for FRM was $212,184. Higher walkability, crime rates, and arterial road exposure were observed for schools with higher percentages of students eligible for FRM. Percentage of students overweight and obese increased with the percentage of students eligible for FRM. Schools with higher percentages of students eligible for FRM tended to have a greater number and percentage of children overweight and obese.

A null model with no explanatory variable was constructed to assess total variance between schools. The z-test ($z = 3.34$, $p = 0.001$) suggests the intercept variance varied between schools, justifying developing a multilevel model. Table 2 shows the results of the unadjusted multilevel logistic regression analyses. Age, sex, percent of students eligible for FRM, crime, walkability, and arterial road exposure were individually associated with the odds of being overweight or obese. The odds of being overweight or obese were 5% (OR 1.05) higher with a one unit increase in age. For males, the odds of being overweight or obese were increased by about 13% compared to females. For schools with 51–74% of students eligible for FRM, the odds of being overweight or obese were 1.51 times higher compared to schools with less than 50% of students eligible for FRM. For schools with 75% or higher of students eligible for FRM, the odds of being overweight or obese were 2.02 times higher compared to schools with $< 50\%$ students eligible for FRM. Taking into account school catchment characteristics, the odds of being overweight or obese were 3.00 times higher with increased crime rates, 2.79 times higher with increased walkability, and 8.55 times higher with increased exposure to arterial roads.

Table 3 shows the results of adjusted multilevel logistic regression analyses. The first logistic regression model included age, sex, and percent students eligible for FRM as explanatory variables. The odds of being overweight or obese were 5% higher with a one unit increase in age, holding the other effects constant. Being male increased the odds that a student would be overweight or obese, holding the other effects constant. For males, the odds of being overweight or obese were multiplied by 1.12 (or the odds were increased by about 12%) compared with females. For schools with 51–74% students eligible for FRM, the odds of being overweight or obese were 1.51 times higher compared

Table 1 Characteristics of students in Public Schools in Spokane, Washington, overall and stratified by percent free and reduced meal students

Characteristics	Percent free and reduced meal students			Total
	Low (≤ 50%)	Middle (51–74%)	High (≥ 75%)	
Number of schools	8	8	12	28
School-level characteristics 2016–2017				
Total enrollment (no.)	3971	3620	5955	13,546
White (no. (%))	3121 (78.59)	2450 (67.68)	3498 (58.74)	9069 (66.95)
Hispanic (no. (%))	301 (7.58)	395 (10.91)	767 (12.88)	1463 (10.8)
Asian (no. (%))	64 (1.61)	70 (1.93)	141 (2.37)	275 (2.03)
Black (no. (%))	63 (1.59)	107 (2.96)	256 (4.3)	426 (3.14)
Indian (no. (%))	22 (0.55)	27 (0.75)	115 (1.93)	164 (1.21)
Special education (no. (%))	612 (15.41)	634 (17.51)	1138 (19.11)	2384 (17.6)
Catchment characteristics				
Median residential property value ($)	212,184	147,265	106,517	148,350
Walkability	0.20	0.48	0.47	0.39
Crime rate per 100 k people	94	349	404	300
Arterial road exposure (%)	41	56	52	50
Access to green space (%)	4.18	3.31	4.15	3.92
mRFEI (%)	35.42	15.69	19.96	23.16
Weight status (2017–2018)				
Students with BMI (no.)	3053	2875	4399	10,327
Classified as overweight (BMI > 85th percentile)	408 (13.36)	431 (14.99)	786 (17.87)	1625 (15.74)
Classified as obese (BMI > 95th percentile)	277 (9.07)	460 (16.00)	853 (19.39)	1590 (15.40)

School-level characteristics obtained from the Washington State Office of the superintendent of public instruction

mRFEI modifed retatil food environment index

Table 2 Unadjusted multilevel analyses of factors associated with being overweight or obese among students in Public Schools in Spokane, Washington

Variables	OR (95% CI)	*t*-statistics	*p* value
Age	1.05 (1.03–1.08)	3.94	< 0.001
Sex			
Female	Reference	–	–
Male	1.13 (1.04–1.23)	2.77	0.006
Percent FRM students			
Low (≤ 50%)	Reference	–	–
Middle (51–74%)	1.51 (1.18–1.93)	3.27	0.001
High (≥ 75%)	2.02 (1.61–2.53)	6.12	< 0.001
Catchment characteristics			
Walkability	2.79 (1.43–5.45)	3.00	0.003
Crime rate per 100 k people	3.00 (1.71–5.26)	3.85	< 0.001
Arterial road exposure (%)	8.55 (2.20–33.24)	3.10	0.002
Access to green space (%)	1.30 (0.02–77.99)	0.12	0.90
mRFEI (%)	1.00 (0.99–1.00)	− 0.95	0.34

FRM free and reduced meal, *mRFEI* modified retail food environment index

to schools with < 50% students eligible for FRM, holding other variables constant. For schools with 75% or higher of eligible for FRM, the odds of being overweight or obese were 2.03 times higher compared to schools with less than 50% students eligible for FRM, holding other variables constant. The multilevel model-based prevalence estimates of overweight or obese were about 15%, 22%, and 27% in schools with lowest, middle and highest percentages of students eligible for FRM, respectively.

In the subsequent models, each individual school catchment characteristic was included in the models along with age, sex, and percent of students eligible for FRM. In these models, school catchment characteristics were not significantly related to the odds of being overweight or obese. The direction and strength of the associations between age, sex, and percent of students eligible for FRM and the odds of being overweight or obese were similar as in the first model.

Discussion

Elementary public schools in Spokane varied substantially in terms of obesity rates, as well as their socioeconomic profiles, and characteristics of the neighborhoods surrounding each school. Our results showed a clear association between

Table 3 Adjusted Multilevel Analyses of Factors Associated with being Overweight or Obese among Students in Public Schools in Spokane, Washington

Variables	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Intercept	0.18 (0.14–0.24)***	0.17 (0.13–0.24)***	0.17 (0.13–0.23)***	0.12 (0.06–0.22)***	0.18 (0.13–0.25)***	0.17 (0.12–0.24)***
Age	1.05 (1.02–1.07)***	1.05 (1.02–1.07)***	1.05 (1.02–1.07)***	1.05 (1.02–1.07)***	1.05 (1.02–1.07)***	1.05 (1.02–1.07)***
Sex						
Female	Reference	Reference	Reference	Reference	Reference	Reference
Male	1.12 (1.03–1.22)**	1.12 (1.03–1.22)*	1.12 (1.03–1.22)**	1.12 (1.03–1.22)**	1.12 (1.03–1.22)**	1.12 (1.03–1.22)**
Percent FRM students						
Low (≤ 50%)	Reference	Reference	Reference	Reference	Reference	Reference
Middle (51–74%)	1.51 (1.17–1.95)**	1.43 (1.04–1.97)*	1.37 (1.02–1.83)*	1.29 (0.94–1.77)	1.52 (1.17–1.97)**	1.57 (1.19–2.07)**
High (≥ 75%)	2.03 (1.61–2.55)***	1.92 (1.43–2.58)***	1.79 (1.33–2.40)***	1.80 (1.38–2.35)***	2.02 (1.60–2.56)***	2.08 (1.63–2.67)***
Catchment characteristics						
Walkability	–	1.22 (0.61–2.43)	–	–	–	–
Crime rate per 100 k people	–	–	1.49 (0.82–2.72)	–	–	–
Arterial road exposure (%)	–	–	–	2.95 (0.78–11.15)	–	–
Access to green space (%)	–	–	–	–	1.28 (0.08–20.94)	–
mRFEI (%)	–	–	–	–	–	1.00 (1.00–1.01)
AIC	45640.78	45645.12	45644.61	45642.42	45642.40	45655.00
ICC (%)	1.56	1.62	1.51	1.46	1.64	1.61

*$p < .05$, **$p \leq .001$, ***$p \leq .001$

AIC akaike information criterion, *FRM* free and reduced meal, *ICC* intraclass correlation coefficient, *mRFEI* modifed retatil food environment index

FRM and the odds of being overweight or obese. We found that schools with higher percentages of students eligible for FRM tended to be surrounded by neighborhoods with higher crime rates and higher exposure to major arterial roads, and both of these neighborhood parameters were strongly associated with the odds of being overweight or obese in bivariate analyses. In the adjusted models, environmental variables were not significant predictors of being overweight or obese in schools. This is likely due to the fact that school-level SES is such a strong indicator of being overweight or obese that it overshadows the school's environmental variables.

Previous studies have found that schools located in lower-SES neighborhoods are less safe when compared to schools located in higher-SES neighborhoods. The impact of neighborhood safety on the mental and physical health of children is well known [31, 32]. Similar to a study in Austin, Texas, our results showed higher walkability scores in neighborhoods of lower-SES. Even though these neighborhoods may be more walkable, the actual propensity to engage in active travel to school may be discouraged by the high crime rates and arterial road density.

Our study results are in line with other research that showed schools serving economically disadvantaged children were located in neighborhoods where the social and built environments were less-healthy and less safe for children [14, 30, 33, 34]. For example, a study examining school proximity to major roads in Canada's 10 largest metropolitan areas found that more than 22% of public elementary schools in lower-income neighborhoods were within 75 m of major roads, while only 13% of schools in higher-income neighborhoods were within 75 m of a major road [30]. The link between increased exposure to air pollution at a younger age and reduced lung functions is well known [35, 36]. A study of 765 schools in Detroit, Michigan also found that the percentage of children eligible for FRM, the percentage of population with income below poverty level, and the percentage of population with no high school diplomas were positively associated with higher traffic within 150 m of schools [33]. A study in Austin, Texas, found that schools with higher poverty rates were located in areas of high crime rates, higher neighborhood-level walkability, and higher rates of students of Hispanic ethnicity. All of these variables were shown to be associated with higher odds of being overweight or obese in lower-SES schools in our study [37].

Strengths and Limitations

The main strength of this study is its use of geographic information systems (GIS) to define the one-mile walking buffer zone around each school as the school neighborhood, instead of relying on the school's official catchment. This allowed us to achieve consistency in terms of our definition of what would be deemed a school neighborhood across the city and enabled us to avoid the 'modifiable area' problem. Our secondary analysis, which used the schools' official catchments to derive the same environmental variables, yielded similar results to the one-mile walking buffer analysis. This seems to indicate that results were not sensitive to change in neighborhood definition in our setting. The primary limitation of this study is the fact the school's environmental and social data span over 3 years (2015–2017). However, no dramatic changes in land use, crime rates, and school data have taken place, over this period, in Spokane.

Conclusions

This study provides further evidence of the link between obesity, poverty, and exposure to poor social and environmental factors [30, 38]. Evidence suggests that societies with larger inequalities also experience a sharper gradient in adverse health outcomes [38]. It is important to acknowledge that measuring the relationship between SES and health outcomes is complex and involves assessing a number of factors including individuals, contextual, historical, and political issues, among others [38]. Based on previous research, the large variability in SES in Spokane, Washington, will likely result in poorer health outcome for children residing in lower-SES neighborhoods. This calls for the adoption of several measures to remedy inequalities in exposure to social and environmental factors.

Implications for School Health

The findings hold several implications for efforts intended to promote child health and reduce inequalities. In Spokane County and in public school districts across the United States, programs aim to promote child health through increased active travel. Since 2005, the federally-funded *Safe Routes to School* program has supported transportation, neighborhood, and school-based initiatives that encourage walking and cycling to schools [39]. A key objective of this initiative is to improve safety and attractiveness of active travel. The reach or effectiveness of *Safe Routes* programs to promote walking to school may be limited where students and families may be concerned about safety. The present results revealed substantially higher crime rates and density of arterial roads within the catchments of lower-SES schools and in schools with more students overweight or obese. Addressing crime rates and reducing or slowing of traffic around schools could play an important role in increasing rates of active travel and improving the mental health of both children and parents. In terms of exposure to air and noise pollution, several solutions are plausible. The concentration of traffic-related air pollution can be addressed both by technical improvements that reduce per-vehicle emissions, such as improved engine efficiency, and urban planning and policy efforts, such as public transit enhancement and cycling infrastructure upgrades. In addition, before building new schools city planners should take into consideration, and possibly avoid, the proximity of major roads and highways. Alternatively, schools situated in proximity to heavy motorized traffic could mitigate noise and poor air quality by installing high efficiency particulate air (HEPA) filters in ventilation systems, sealing windows and doors, or using double-glazed windows in classrooms.

Author Contributions OA and PM: Conceptualization. OA, PM and SA: Methodology. SA: Software. OA and PM: Validation. RL: Resources. AC: Data Curation. OA, SA and PM: Writing-Original Draft Preparation. PM, RL, SA, AC and OA: Writing-Review & Editing.

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Compliance with Ethical Standards

Ethical Approval The Washington State University Office of Research Assurances determined that this study satisfied the criteria for Exempt Research.

Conflict of interest Conflict of Interest: The authors declare that they have no conflict of interest.

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