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RESEARCH ARTICLE

School Context Matters: The Impacts of Concentrated Poverty and Racial Segregation on Childhood Obesity*

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ABSTRACT

BACKGROUND: Schools are important sites for interventions to prevent childhood obesity. This study examines how variables measuring the socioeconomic and racial composition of schools and counties affect the likelihood of obesity among third to fifth grade children.

METHODS: Body mass index data were collected from third to fifth grade public school students by teachers from 317 urban and rural North Carolina schools in 38 counties. Multilevel models are used to examine county-, school-, and individual-level effects.

RESULTS: Low concentrations of poverty at the school level are associated with lower odds of obesity. Schools in rural counties had significantly higher rates of obesity, net the other variables in the model. Students in minority-segregated schools had higher rates of obesity than those in more racially diverse schools, but the effect was not statistically significant once school-level poverty was controlled.

CONCLUSIONS: Place-based inequalities are important determinants of health inequalities. The results of this study show that school-level variables related to poverty are important for understanding and confronting childhood obesity.

Keywords: childhood obesity; place-based inequality; school socioeconomic status; racial segregation; school racial composition.

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The World Health Organization called childhood obesity ''one of the most serious public health challenges of the 21st century.''[1] Since the 1980s, the obesity rate in the United States has tripled to approximately 17% for children aged 2-19.[2-4] Given these rates, some researchers argue that average life expectancy may be shortened by 2 to 5 years.[5]

Neighborhood/community environments are labeled obesogenic due to the linkages among characteristics of their built and food environments, their socioeconomic and demographic compositions, and obesity rates.[6-15] The environments in which children live and attend school also have well-established links to health disparities. Racial and economic segregation at the school level are associated with poorer academic and health outcomes for minority and low-income children as compared to students in less segregated school environments.[16-21]

For low-income children, schools may be a place to either mitigate or exacerbate the disadvantages associated with their own neighborhoods or with their households.[22] Studies show that schools may matter more for obesity than family resources,[17] and are effective sites for child obesity interventions.[20,23,24] Much in the same way that residential racial segregation restricts the amount of resources available in communities, students in high-minority schools are likely to have fewer available resources.[25-27] In a study of New York City public school children using individual- and school-level variables,[16] obesity was

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related to characteristics of the schools, including the percent of students receiving free/reduced lunch, after controlling for individual-level variables.

Income segregation, the concentration of people in neighborhoods based on income and/or wealth, is a persistent feature of the US residential landscape.[28] As income inequality has become even more pronounced in the United States over the last decade, the process of ''segregation of affluence'' has accompanied the ''segregation of poverty.''[29] Residential segregation by race is also prevalent in the United States and is correlated with measures of neighborhood disadvantage.[27] Living in racially segregated or economically disadvantaged neighborhoods is associated with higher rates of obesity according to studies of residents of urban areas.[9,11,30-33] Other studies confirm that racial discrimination impacts a number of health outcomes among youth and children.[34]

Whereas schools and their associated communities are important structural contexts for understanding health outcomes, they are not always examined together or include both rural and urban spaces.[35] This study examines childhood obesity and its relationship to racial segregation and concentrated poverty at both the school and community levels with a set of data from North Carolina (NC) children from urban and rural counties. Using multilevel models, we examine the effects of school-level poverty and racial segregation in both rural and urban schools, while controlling for county-level socioeconomic disadvantage, county-level racial segregation, and individual-level characteristics. We examine if (1) students at schools with high-poverty concentrations have higher rates of obesity compared to students at economically integrated schools, net of individual- and county-level variables; (2) students at racially segregated schools have higher rates of obesity compared to those at racially integrated schools; and (3) county-level racial segregation and high socioeconomic disadvantage affect the likelihood of obesity net of school- and individual-level variables.

METHODS

Study Population and Sample Data

The data used were collected in third to fifth grade physical education (PE) as part of the ''In-school Prevention of Obesity and Disease'' (IsPOD), a statewide initiative in NC to increase training and physical activity in schools (These data were supplied by the North Carolina Alliance for Athletics, Health, Physical Education, Recreation and Dance (NCAAHPERD), which specifically disclaims responsibility for any analyses, interpretations, or conclusions it has not provided.). PE teachers were encouraged to participate in free continuing education classes in which they received curriculum guidance to increase the activity level of all students. As part of their participation, PE teachers were given and trained to use FitnessGram™ software[36] to record demographic characteristics and the height and weight of their students. This software was also used in a study of students in New York City schools.[16] When available, PE teachers measured height and weight using a scale and attached height bar. However, not all schools were equipped with scales and, for these schools, teachers asked the students to report on their height and weight. The method of data collection for these variables is not indicated in the recorded information.

Data for this research come from the records collected during the first year (2009-2010) of the program. If a student's FitnessGram™ record did not have valid height and weight data, then they were considered ''missing'' and eliminated from the data used in this analysis. Schools that submitted usable height and weight for less than 10% of their third through fifth grade students were omitted from this study. A majority of the omitted schools came from counties in which no other schools had submitted data. In all, 5% of the schools were dropped. Students in lower and higher grades were eliminated from this study's sample data for 2 reasons: first, they were not the target group, and therefore, data were limited and second, the onset of puberty in older students can complicate body mass index (BMI) estimates. The mean response rate for schools included in the data used in this study is 91% (with a standard deviation of 0.13). This was calculated using the number of valid records from PE teachers divided by the number of third to fifth grade students enrolled at participating schools.

The way in which the PE teachers recorded the individual-level student height and weight data introduces potential bias into the measurement of obesity. Asking a young student for her/his height and weight is a common practice, but it is undoubtedly a source of error. However, obesity researchers argue that respondents tend to overestimate height and underestimate weight in self-reports, thereby underestimating obesity and making the error in self-report in the conservative direction.[37] The NC students could also reply that they ''do not know.'' Given that cases without measures for height and weight were dropped and that schools with substantial omitted data were also dropped, some of this type of error is eliminated, but not all of it. The final data set for this analysis included information on 74,665 students from 317 different schools. Thirty-eight NC counties had one or more schools that participated in the project that produced the student-level data.

Study Variables, Measures, and Statistical Methods

In addition to height and weight, teachers used FitnessGram™ software to record their students' date of birth, race/ethnicity, and grade. These student

demographic variables were verified using the school's administrative data. When there was a conflict between the teacher-entered data and the administrative data, the administrative data were used. The dependent variable, whether or not a student is obese, comes from the data recorded by the PE teachers. Each student's recorded height and weight was used to calculate their BMI (BMI = weight (kg)/(height (m) × height (m)) and calculate their pediatric BMI to enable comparisons with children of different ages. The student's BMI was then plotted on a US Centers for Disease Control and Prevention growth chart to determine her/his percentile for their sex and their age at the time of the test. In the statistical models, students with BMI scores in the 95th percentile or higher were considered obese[38] and were coded with ''1'' for the ''obesity'' variable. Students were coded as ''0'' if they were not obese.

Because student records were deidentified in accordance with human subjects' protocols and did not include any information on the student's address or free and reduced lunch status, we were unable to measure the students' household poverty status. The individual-level variables in the data set included the student's grade (continuous), sex[39] (female = 1 and male = 0), and race. Teachers recorded Hispanic ethnicity and racial classification in the original records. If the original student record contained more than one race and/or ethnicity, the student was considered ''multiracial.'' For the statistical analysis, we recoded the teachers' classifications of students into a set of dummy variables: ''white,'' ''Hispanic,'' black,'' or ''other.'' ''Other'' was a multiracial category and included individuals with more than one racial/ethnic category. ''White'' was used as the omitted reference category in the models.

The individual-level student information in the NC data included the local education area and the school number. Using this information, we linked each student record with school-level and county-level characteristics from publically available administrative data.[40-42] We operationalized concentrated poverty at the school level as a set of dummy variables using the percentage of students in each school that receive free or reduced lunch.[40] Consistent with other concentrated disadvantage studies,[25] if 75% or more of the students were receiving a free or reduced lunch, the school was coded as ''high poverty,'' and schools with less than 25% were coded ''low poverty.'' Schools that were neither high nor low poverty were considered ''economically integrated'' and were the omitted category in the models. This school-level variable reflects the income of the students' households.

Other publicly available Department of Public Instruction data[41] were used to calculate and operationalize minority segregation at the school-level. Schools are considered ''minority segregated'' if 75% or more of the students are nonwhite. Schools were coded ''white segregated'' when 75% or more of the student body is white. Each of these school-level dummy variables is compared to the omitted category that is ''no racial segregation'' in the statistical models.[25,43]

Our study differs from others[6] in that we did not have access to student residential addresses, and therefore, could not measure neighborhood context by using a set of zip codes or census enumeration tracts that link students and schools. We use county as our unit of analysis for the operationalization of variables measuring community context. County is often used as a measure of place-based context in studies of the spatial distribution of inequality.[44-46] An advantage of using county as the measure of place-based context is that it allows us to compare urban and rural counties. County-level measures of socioeconomic disadvantage and of racial segregation were adopted from the Rural Data Bank which compiles data on NC counties from the US Census and the American Communities Survey.[42] Data controlling for food access are from the US Department of Agriculture (USDA).[47]

Socioeconomic disadvantage for a county is operationalized with 2 variables: the percentage of households receiving Supplemental Nutrition Assistance Program (SNAP) and the percentage of people who are uninsured.[48] These 2 variables reflect the degree to which the county-level geographical areas that are associated with schools have a disadvantaged socioeconomic environment. To calculate county-level racial segregation, we used dissimilarity indices that measure the evenness of the distribution of 2 groups among small geographic units (ie, census tracts) within a larger geographic unit (ie, county). For example, the formula for calculating the dissimilarity index between black and white households for a county is: $\frac{1}{2}\sum_{i=1}^{N}\left|\frac{b_i}{B}-\frac{w_i}{W}\right|$. This is a commonly used measure of residential segregation.[49] Two variables were calculated: a black/white dissimilarity index and a Hispanic/white dissimilarity index. In addition to the indices of race/ethnic dissimilarity, we used a dummy variable to identify rural counties in the models.[42,50] Rural counties were coded as ''1'' with urban counties as the omitted category.

To control for differences in the county food environment, we used data from USDA studies of food deserts.[47,51] According to the USDA, a census tract is considered a food desert if 33% or more of the county's population lives a significant distance from a grocer. In the USDA classification of food deserts, significant distance is defined as >10 miles for rural counties and >1 mile for urban. If a NC county had one or more food deserts within it according to the USDA, we coded the food desert variable as ''1'' (counties without food deserts were the omitted category) in the statistical models.

Table 1. **Descriptive Statistics for All Key Variables**

Variable	Mean/ Frequency	SD	Minimum	Maximum
Student-level variables (level 1) N = 74,665				
Obesity				
Obese	20%			
Not obese (omitted)				
Sex				
Female	49%			
Male (omitted)				
Race				
Black	25%			
Hispanic	13%			
Other	8%			
White (omitted)				
Grade	3.99	0.81	3.00	5.00
School-level variables (level 2) N = 317				
Racial segregation				
Minority segregated	27%			
White segregated	24%			
No racial segregation (omitted)				
Poverty				
High poverty	29%			
Low poverty	14%			
Medium poverty (omitted)				
County-level variables (level 3) N = 38				
Urban/rural				
Rural county	79%			
Urban county (omitted)				
Residential segregation				
Black/white dissimilarity index	0.37	0.11	0.05	0.57
Hisp/white dissimilarity index	0.27	0.11	0.08	0.48
Socioeconomic disadvantage				
% SNAP	14%			
% Uninsured	20%			
Food desert				
Food desert counties	63%			

SD, standard deviation; SNAP, Supplemental Nutrition Assistance Program.

Descriptive statistics were calculated for all variables, including the student-level, school-level, and county-level measures. Next, to effectively model the multiple characteristics of students and place, both school and county, we use multilevel logistic regression.[52] Estimation of these models was done using the PROC GLIMMIX procedure in base SAS 9.4 software.[53] To determine the amount of variation across students, across schools, and across counties, we first ran a 3-level model without any predictor variables to confirm that there was statistically significant variation at each level. Next, we ran a model including individual-level measures at level 1, followed by the addition of school-level measures at level 2, and finally the full model that included county-level measures at level 3. To investigate how school-level economic segregation might differ from racial segregation, we calculated a model with the school-level poverty variable first and then a model with both school-level poverty and racial segregation variables second.

RESULTS

Table 1 shows the descriptive statistics for the NC sample used in this study. About 20% of the students in this NC sample are obese (17.5% of youth aged 6-11 were obese in the United States for 2011-2014).[4] The sex balance in the sample is similar to the state population for the relevant student grade levels, with slightly fewer girls than boys. The sample in this study has slightly fewer African Americans than the state as a whole: 30% statewide versus 25% in study. Slightly less than half of the schools are racially integrated, with 27% white-segregated and 24% minority-segregated. Almost 30% of the schools in the sample are high poverty and about 14% are classified as very low poverty. The majority (80%) of the 38 counties represented in the sample are rural (the majority of all NC counties are rural), and the average percentage of households in the sample counties receiving SNAP benefits is 14%. Residential segregation within counties varied from 0.05 to 0.57

Table 2. **Multilevel Logistic Regression Results Predicting Odds of Obesity (N = 74,665 Students, 317 Schools, 38 Counties)**

	Model 1: Base		Model 2: Student-Level		Model 3: School-Level Poverty		Model 4: School-Level Poverty and Race		Model 5: County-Level Full Model	
Variable	**Odds Ratio**	**Coeff. (SE)**	**Odds Ratio**	**Coeff. (SE)**	**Odds Ratio**	**Coeff. (SE)**	**Odds Ratio**	**Coeff. (SE)**	**Odds Ratio**	**Coeff. (SE)**
Constant	0.27	−1.31* (0.04)	0.19	−1.67* (0.07)	0.19	−1.66* (0.07)	0.19	−1.67* (0.07)	0.26	−1.35* (0.46)
−2 Res Log Pseudo-Likelihood		352462		353575.9		353733.6		353756.5		353787.5
Sex										
Female (=1)			0.85	−0.16* (0.02)	0.85	−0.16* (0.02)	0.85	−0.16* (0.02)	0.85	−0.16* (0.02)
Race										
Black (=1)			1.71	0.54* (0.03)	1.65	0.50* (0.03)	1.65	0.50* (0.03)	1.65	0.50* (0.03)
Latino/a (=1)			1.99	0.69* (0.03)	1.91	0.65* (0.03)	1.91	0.65* (0.03)	1.91	0.65* (0.03)
Other (=1)			1.32	0.28* (0.04)	1.30	0.26* (0.04)	1.30	0.26* (0.04)	1.30	0.26* (0.04)
Grade			1.06	0.06* (0.01)	1.06	0.06* (0.01)	1.06	0.06* (0.01)	1.06	0.06* (0.01)
Segregation										
Minority seg (=1)							1.10	0.09 (0.07)	1.13	0.13 (0.07)
White seg (=1)							1.05	0.05 (0.05)	1.01	0.01 (0.06)
Poverty										
High poverty (=1)					1.15	0.14* (0.04)	1.11	0.10 (0.06)	1.08	0.08 (0.06)
Low poverty (=1)					0.63	−0.46* (0.06)	0.63	−0.46* (0.06)	0.66	−0.42* (0.06)
Food desert (=1)									0.88	−0.13 (0.10)
Rural county (=1)									1.25	0.23* (0.10)
Black/white dissimilarity index									1.35	0.30 (0.39)
Hispanic/white dissimilarity index									0.55	−0.61 (0.47)
% Food stamps									8.03	2.08* (0.92)
% Uninsured									0.05	−2.94 (1.95)
School-level covariance		0.17* (0.02)		0.11* (0.01)		0.07* (0.01)		0.07* (0.01)		0.07* (0.01)
County-level covariance		0.02* (0.02)		0.05* (0.02)		0.04* (0.02)		0.05* (0.02)		0.02* (0.01)

*$p < .05$.

and the range was similar for both Hispanic and white segregation and black and white segregation.

Model 1 in Table 2 is an empty model showing that there is a statistically significant difference between schools and counties. Model 2 in Table 2 adds the individual-level/student measures in the 3-level model. The odds of obesity for black children in Model 2 are about 1.7 times the odds for whites, and Hispanic youth's odds are 1.99 times that of white children. Children of ''other'' races had odds that were 1.3 times the odds of white children in the model.

Models 3 and 4 present the results for the addition of the school level for concentrated poverty and racial segregation, respectively. In these models, all of the individual-level student variables from Model 2 remained statistically significant and were in the same direction. However, the effects of these individual-level variables on the odds of obesity decreased slightly. For example, in Model 4, the odds for black youth being obese in the sample is 1.6 compared to the odds of whites in the sample, which is slightly down from 1.7 in the prior model. The odds of obesity for Hispanic children decreased by a little less than 0.08 relative to whites, net of the other variables in the model. The effect of grade on the odds of obesity remained consistent.

High-poverty schools had a statistically significant and positive effect on the likelihood of obesity, net the other variables in Model 3. The odds of a student in a high-poverty school being obese are about 1.15 times that of children in economically integrated schools. Conversely, students in low-poverty schools have lower odds of being obese compared to students in economically integrated schools. Model 3 predicts that the odds of obesity for students in low-poverty schools are 0.63 times that of students in economically integrated schools, net the other variables in the model.

Model 4 adds the school-level racial segregation variables to the model. Even after school-level racial segregation is controlled, the predicted difference in obesity rates between low-poverty and economically integrated schools remains statistically significant and negative. The relationship between high-poverty schools and economically integrated schools remains positive, but is only significant at the 0.08 level. Net the other variables in the model, the odds of students in low-poverty schools being obese are about 0.63 times that of students in economically integrated schools, according to the results of Model 4.

Model 5 is the full model and includes county-level variables. School-level poverty measures are still statistically significant. Racial segregation measures at

the school level remain nonsignificant. Rural counties did have a statistically significant effect on obesity, with residency in rural counties predicting higher odds of obesity. The percent of families in the county receiving SNAP benefits, a measure of socioeconomic disadvantage, has a statistically significant and positive effect on the likelihood that a child will be obese in Model 5. The 2 measures of racial segregation within counties were not statistically significant. The measure of food deserts at the county level was not a statistically significant predictor of obesity in the final model.

DISCUSSION

The role of school socioeconomic environments is important for understanding childhood obesity. The effects of individual-level characteristics in this analysis are consistent with studies that find persistent racial and ethnic differences in health outcomes.[15,54] We find that students in high-poverty schools have higher rates of obesity compared to students in economically integrated schools. In addition, we find that students in schools that are socioeconomically isolated from those in poverty had significantly lower rates of obesity compared to students in economically integrated schools, controlling for the individual-level student variables. This effect held even once racial segregation was controlled at the school-level.

Second, we examined if students in minority-segregated schools (75% or more nonwhite) have higher rates of obesity compared to those at schools with no racial segregation, again controlling for individual-level student variables. We find that while children in minority-segregated schools had higher rates of obesity than those in more racially diverse schools, the effect was not statistically significant once we accounted for school-level poverty. This is consistent with other research that shows that children have higher rates of obesity in minority-segregated schools[21] and that racial and economic segregation at the school level impacts student outcomes.[55] However, our results also indicate that the relationship between school-level racial segregation and concentrated poverty is complicated and requires further exploration.

Other multilevel analyses find that measures of county-level socioeconomic disadvantage and racial segregation context impact obesity rates and other measures of health.[11,13,15,56,57] Our 2 measures of county-level racial segregation did not have significant effects on obesity net of the school-level and individual-level variables in the multilevel models. Consistent with prior work, the county-level measure of food deserts in the final model did not have an effect on the measure of students' obesity.[10] However, in the multivariate final model, rural residency and county-level socioeconomic disadvantage (percent of families receiving food stamps) were risk factors of childhood obesity. The results concerning the higher obesity rates among students from rural versus urban counties require further investigation of the exact nature of the rural context. The significant effect for the rural versus urban county dummy variable may reflect unmeasured differences in the built environment, the geography of food access, or additional aspects of space and place inequalities not completely captured by our county-level measures. In addition, the operationalization of community context may require different geographies for measures of urban schools (eg, a residential neighborhood as defined by census tracts) than for rural schools (eg, a county-level measure), given rural-urban differences in the size of school districts.

Limitations

Whereas our results provide information on the effects of school and place-based inequalities on children's obesity rates, there are several limitations. We are unable to control for poverty at the student, family, or census tract/neighborhood level in the statistical models. If we had such control variables in the models, the school-level effects of poverty might be diminished. Similarly, while the percent of students receiving a free or reduced lunch is a well-vetted measure of school-level poverty, this study does not include measures of household income or wealth inequality among students aggregated at the school level. Not including a measure of wealth, or affluence, is a common limitation in studies of inequality.[25]

Although we believe that this data set has unique features that make it an appropriate starting point for examining county-level effects, better measures of rural-urban differences are needed to investigate rural-urban county-level differences in obesity rates. Measures of the built environment and access to exercise would also be helpful. In addition, because the data were drawn from schools from 38 of the 100 counties in NC, it is possible that there is a selection bias in which counties chose to participate and which schools within the counties participated in the data collection. Differences in rates of food insecurity[58] or physical activity levels or the ability to access nutritious food may account for the rural versus urban county-level difference.[12,58,63] By better understanding the processes by which students in disadvantaged schools and communities, particularly in rural areas, come to experience higher rates of obesity, we can improve interventions to ameliorate health disparities among students.

Conclusions

Schools are key settings for a variety of obesity prevention activities and policies including healthy eating,

nutrition, and PE interventions.[20,23,24] Schools are also important settings for addressing the inequalities that exist among individual students. This research shows that socioeconomic inequality at the school level matters for childhood obesity outcomes, even when other variables measuring county-level and individual-level characteristics are controlled. Specifically, more attention and resources are needed in schools with high and medium concentrations of poverty to help decrease health inequalities and minimize obesity. Schools in rural areas need further study to better understand how obesity can be decreased in these particularly vulnerable areas.

IMPLICATIONS FOR SCHOOL HEALTH

This research is part of a larger debate about the roles of structural racism and socioeconomic inequalities as fundamental causes of health disparities.[59] The empirical results are an initial step in understanding how school and place-based socioeconomic disadvantages and racial segregations impact student health disparities. Efforts to minimize health inequalities should involve not only high-poverty schools and communities but also schools with moderate poverty and address the economic segregation that separates wealthy students and communities from everyone else. As counties and residential neighborhoods stratify in such a way that children of middle and low socioeconomic status are isolated from wealthier families, health and school officials will need to review their efforts at minimizing disparities among schools. Public education provides an opportunity to minimize some of the negative health effects of family and individual poverty. However, if schools remain socioeconomically segregated, the ability of educational institutions to foster equality is greatly diminished.

Many policies designed to prevent or decrease obesity are directed at the individual level. These include advocating more exercise, eating less fast food, and reducing screen time among children. There are cases of successful school and place-based efforts that can serve as exemplars for interventions. For example, a coalition of parents, educators, and public officials in Philadelphia changed the food environment in the public schools (eg, removing sugary drinks from vending machines) and developed policies to increase the availability of healthy food in low-income neighborhoods.[60] This research adds to this conversation by showing the importance of place-based approaches that not only address behaviors, but also the environmental amenities necessary to maintain a healthy weight status. Future research should continue to investigate and identify the contextual inequalities that minimize or exacerbate health disparities.[61,62]

Racially and economically integrating schools has been a topic of much debate in the United States. Whereas it is well established that integrated schools can help to lower the achievement gap among students, there are also health implications for segregating students based on race and socioeconomic status. Because neighborhoods tend to be segregated along these lines, school boards must be willing to enact policies to counteract spatial separation. In a study of low-income students from Maryland, Schwartz[55] shows that policies promoting housing and economic integration can have positive outcomes on school achievement. A holistic approach that minimizes differences between high-income schools and less privileged schools ought to be a priority for public health policy makers. Physical activity and health education should be equally accessible to all students. Schools have a unique opportunity to minimize inequalities that exist between students. In the case of child health, schools have the potential to improve long-term health outcomes.

Human Subjects Approval Statement

Permission to use the student data was granted from the North Carolina Alliance for Health, Physical Education, Recreation, and Dance who managed the data collection and our host institution's Institutional Review Board approved this research. Whereas these data were supplied by the North Carolina Alliance for Athletics, Health, Physical Education, Recreation and Dance (NCAAHPERD), it specifically disclaims responsibility for any analyses, interpretations, or conclusions it has not provided.

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