Test file: Association Between Neighborhood Food Environment and Childhood Obesity: A Spatial Epidemiological Analysis

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Abstract

This comprehensive spatial epidemiological study investigates the complex relationships between neighborhood food environment characteristics and childhood obesity prevalence across 45 metropolitan regions. Utilizing multi-level data from 25,682 children aged 6-12 years, combined with detailed geographic information systems mapping of 12,450 food outlets, we demonstrate significant spatial clustering of obesity risk in neighborhoods with high fast-food density and limited healthy food access. After adjusting for individual and neighborhood-level confounders, each additional fast-food outlet within an 800-meter school buffer was associated with an 11% increase in obesity odds, while supermarket availability demonstrated protective effects. Spatial regression models revealed significant moderation by neighborhood socioeconomic status, with stronger food environment effects observed in low-income communities. These findings provide robust evidence for urban planning policies addressing obesogenic food environments.

Keywords: Childhood Obesity; Food Environment; Spatial Epidemiology; Fast Food; Neighborhood Effects; Multi-level Analysis; Geographic Information Systems

1. Introduction

Childhood obesity represents one of the most pressing public health challenges of the 21st century, with global prevalence rates having increased more than eight-fold over the past four decades. The complex etiology of obesity extends beyond individual-level factors to encompass broader environmental determinants, particularly the neighborhood food environment. Ecological models of health behavior posit that environmental contexts significantly influence dietary patterns through availability, accessibility, and affordability of different food types. The spatial distribution of food outlets creates distinct food landscapes that may either promote or discourage healthy eating behaviors among children. While numerous studies have examined food environment-obesity relationships, methodological limitations including inadequate spatial precision, limited confounder adjustment, and insufficient attention to effect modification have constrained causal interpretation and policy relevance. This study employs advanced spatial epidemiological methods to comprehensively characterize neighborhood food environments and examine their associations with childhood obesity prevalence, while addressing key methodological challenges through multi-level modeling, spatial autocorrelation adjustment, and detailed examination of contextual effect modifiers. The findings aim to inform evidence-based urban planning and public health interventions targeting obesogenic food environments.

2. Methods

2.1 Study Population and Design

We conducted a cross-sectional study of 25,682 children aged 6-12 years from 45 metropolitan regions across the United States between 2021 and 2023. Participants were recruited through school-based health examinations, with anthropometric measurements conducted by trained staff using standardized protocols. Obesity was defined using CDC growth charts (BMI ≥95th percentile for age and sex). The study received ethical approval from the institutional review board, and written informed consent was obtained from parents or guardians.

2.2 Food Environment Assessment

Comprehensive food environment data were collected from multiple sources including business licensing databases, commercial directories, field validation surveys, and satellite imagery. Using geographic information systems, we characterized food environments through multiple metrics: fast-food outlet density, supermarket availability, convenience store prevalence, healthy food index, and food outlet mix diversity. Analyses employed network buffers around both school locations and residential addresses to capture children's primary food environments. Additional measures included proximity to nearest healthy and unhealthy food outlets, and spatial accessibility indices accounting for transportation networks and population density.

2.3 Covariate Measurement

Individual-level covariates included age, sex, race/ethnicity, parental education, household income, and physical activity levels. Neighborhood-level characteristics encompassed socioeconomic status, population density, street connectivity, park availability, and crime rates. School-level factors included nutrition policies, physical education requirements, and proximity to food outlets. Data were obtained from census records, school administrative databases, and municipal planning departments.

2.4 Spatial Statistical Analysis

We employed multi-level logistic regression models with random intercepts for census tracts to account for geographic clustering. Spatial autocorrelation was assessed using Global and Local Moran's I statistics. To address spatial dependence, we implemented spatial error models and geographically weighted regression. Sensitivity analyses examined different buffer sizes, alternative food environment metrics, and various spatial weighting schemes. Effect modification was tested through interaction terms and stratified analyses.

3. Results

3.1 Spatial Patterns of Food Environment and Obesity

Significant spatial clustering was observed for both food environment characteristics and childhood obesity prevalence. Fast-food outlets demonstrated substantial spatial aggregation in lower-income neighborhoods and near schools, while supermarkets showed more dispersed patterns. Childhood obesity prevalence varied nearly threefold across neighborhoods, with clear spatial patterning along socioeconomic gradients. Global Moran's I statistics confirmed significant spatial autocorrelation for both exposure and outcome variables.

3.2 Food Environment-Obesity Associations

After comprehensive adjustment for individual and neighborhood-level confounders, fast-food outlet density showed strong positive associations with childhood obesity. Each additional fast-food outlet within 800 meters of schools was associated with an 11% increase in obesity odds. Supermarket availability demonstrated protective effects, with each additional supermarket

associated with a 7% reduction in obesity odds. The healthy food index, combining multiple food environment dimensions, showed particularly strong protective associations. Spatial regression models accounting for autocorrelation yielded similar effect estimates, though with improved model fit and reduced residual spatial patterning.

3.3 Effect Modification and Contextual Influences

Neighborhood socioeconomic status significantly modified food environment effects, with stronger associations observed in low-income communities. In high-poverty neighborhoods, fast-food density showed 40% larger effects on obesity risk compared to affluent areas. School nutrition policies also moderated relationships, with stronger food environment effects in schools lacking comprehensive nutrition standards. Racial/ethnic composition modified associations, with particularly strong fast-food effects in predominantly Hispanic neighborhoods.

4. Discussion

4.1 Interpretation of Spatial Patterns

This large-scale spatial analysis reveals substantial geographic inequities in both food environment characteristics and childhood obesity prevalence. The clustering of obesogenic food environments in disadvantaged neighborhoods underscores the role of structural factors in shaping health disparities. The stronger food environment effects observed in vulnerable communities highlight the potential for targeted interventions to reduce obesity inequities. The spatial methods employed in this study provide more precise effect estimates by properly accounting for geographic dependencies that violate traditional statistical assumptions.

4.2 Policy Implications and Intervention Strategies

The findings support several evidence-based policy approaches. Zoning regulations limiting fast-food outlet density, particularly near schools and in vulnerable neighborhoods, represent a promising strategy. Economic incentives for supermarket development in food deserts could improve healthy food access. School nutrition policies should be strengthened to buffer children from obesogenic community environments. Comprehensive approaches combining food environment modifications with nutrition education and economic interventions are likely to yield the greatest population health benefits.

4.3 Methodological Considerations and Limitations

While this study advances methodological rigor through spatial analysis techniques, several limitations warrant consideration. The cross-sectional design precludes causal inference, though the spatial-temporal patterns provide suggestive evidence of environmental influences. Unmeasured confounding remains possible despite comprehensive covariate adjustment. Food environment measures based on outlet presence may not fully capture food quality, affordability, or consumer purchasing patterns. Future research should incorporate longitudinal designs, direct food purchasing data, and policy intervention evaluations.

5. Conclusion

This spatial epidemiological analysis provides robust evidence that neighborhood food environment characteristics significantly influence childhood obesity risk, with particularly strong effects in socioeconomically disadvantaged communities. The findings underscore the importance of addressing obesogenic food environments through comprehensive urban planning and public health strategies. Policy makers should prioritize evidence-based interventions targeting food

environment modifications, particularly in vulnerable neighborhoods, as part of multi-sectoral approaches to childhood obesity prevention. Future research should focus on evaluating specific policy interventions, understanding causal mechanisms, and developing targeted strategies for populations at highest risk.

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