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Community and child energy balance: differential associations between neighborhood environment and overweight risk by gender

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Abstract

Using data from the 2003 to 2004 continuous National Health Nutrition Examination Survey merged with the 2000 census and other geographic information systems-based neighborhood data, this study conducted gender-specific analyses to examine the influence of neighborhood characteristics on child risk for overweight (defined as gender-specific body mass index which is greater than the 85 percentile). Models of neighborhood influence that include institutional factors, built environment factors, and social modeling dynamics were tested. The study sample included 1753 (915 girls and 838 boys) children aged 2–11 years. Results indicate that institutional neighborhood features such as poverty in the census tract and rurality are associated with higher odds of risk of child overweight. Built environment factors also have connections to child risk of overweight, with long commute times within the census tract associated with higher overweight risk. Higher prevalence of physical activity is associated with lower risk of child overweight. Gender-specific analyses reveal that a higher prevalence of obesity (defined as BMI of greater than 30) within a census tract has a protective association with girls' risk of overweight. Boys' risk of overweight is associated with living in rural areas. These findings point to the importance of examining environmental aspects of child risk of overweight.

Keywords

health; housing conditions

Introduction

Obesity or overweight in the USA is an increasing major health issue in recent decades (Ogden et al. 2008). While many industrialized countries have experienced similar increases, obesity rates in the USA are among the highest in the world. The persistently high prevalence of childhood overweight in the USA is particularly alarming given the detrimental health consequences of overweight in early life throughout the life course. Between 2003 and 2006, 16.3% of children and adolescents were overweight (Centers for Disease Control and Prevention 2009). To better understand the etiology of childhood overweight, it is important to explore risk factors that lie in multiple levels and dimensions of life domains of children's routine activities.

The neighborhood environment is a key context impacting on child overweight risk progression is located as this is a broader context in which individual behaviors are influenced by elements of both the physical environment and local norms for behavior and

attitudes about physical activity and weight-related decision making for both parents and their children. As such, the neighborhood represents an important setting for policy modification and obesity interdiction.

However, estimates of the linkages between features of institutional neighborhood factors and measures of the built environment and child overweight are just now starting to emerge in the literature. Studies linking neighborhood effects to childhood overweight risk have been impeded by the lack of data that contains both reliable national estimates on childhood overweight risk and measures of the social environment in which the children reside. Additional research is needed that takes advantage of relatively recent advances in geographic information systems (GISs) approaches to describing the neighborhood environment.

Child overweight risk is potentially influenced by multiple factors within the neighborhood (Shaw & McKay 1942; Jencks & Mayer 1990; Sampson et al. 1997; Kawachi & Berkman 2003). Neighborhoods could potentially influence child overweight risk via three important pathways: institutional factors, built environment factors, and social modeling.

Institutional factors such as neighborhood economic resources and rurality can impact childhood overweight risk. Oliver and Hayes (2005) find evidence of a socio-economic gradient in the prevalence in child overweight. Living in a low SES neighborhood has an independent influence on child body mass index (BMI). They conjecture that less affluent neighborhoods have social and physical environments less conducive to maintaining a healthy bodyweight. Fewer children may be participating in organized physical activity and this might be due to a lack of local facilities and resources and also because of a lack of awareness or motivation. The rurality of a community can also act as an institutional factor as rural areas are settings that have been identified to have higher risk for childhood overweight risk. Some studies have linked a lack of nutrition education and services to childhood overweight (Leeper et al. 2001; Omar et al. 2001), while others have observed that rural areas have fewer physical education classes in schools and fewer exercise facilities (Hendryx 1993; Heneghan & Malakoff 1997).

A growing body of research provides evidence of the potential importance of the built environment for energy balance decisions (Smith et al. 2008; Smith et al. 2011; Zick et al. 2009). One aspect of the built environment that has been identified as important is the walkability of the environment. People who live in sprawled counties, with low walkability, are less likely to walk in their leisure time, have higher BMIs, and are more likely to have high blood pressure and be obese (Heath et al. 2006). Communities where higher proportions of residents commute long distances are likely associated with higher obesity and lower physical activity (Smith et al. 2011). These communities are likely to be characterized by remoteness from areas of active transportation and leisure. Previous research on the interaction between human health and the physical environment suggests that exposure to green landscapes has a positive influence on the variety of psychological and physiological processes (Garcia et al. 1995; Wells & Evans 2003). Green outdoor settings have been linked to greater supervised use by children for activity (Lachowycz & Jones 2011). Shade from tree canopy and scenery from green spaces have been associated with reports of increased walking as well as other better health outcomes (Chaudhury 1994; Coley et al. 1997; Sallis et al. 1997; Taylor et al. 1998). Liu and others (2010) find that increased neighborhood vegetation was associated with decreased risk for overweight for children living in higher population density regions.

Social modeling factors present within a community are also important in creating an obesogenic environment (Ard 2007). Elementary school-aged children are spending

increasing time in social environments and as such are engaging in social comparison behaviors (Eccles 1999). Neighborhoods with visible evidence of other residents participating in physical activity may influence residents to adopt similar healthy behaviors. Conversely, neighborhoods with higher proportions of overweight residents may contribute to an environment where residents may be more likely to engage in weight behavior and outcomes more consistent with their visible surrounding peers. More research is needed to investigate this potential dynamic. In this analysis, we consider whether boys and girls are differentially responsive to institutional factors, built environment factors, and social modeling processes in their proximate environments.

We consider whether girls and boys might respond differently to neighborhood environments with respect to their risk of overweight. Parents might place fewer restrictions on boys' activities outside of the home based on perceived safety risks of the neighborhood environment. This dynamic might lead to a differing pattern of neighborhood amenities being more salient for boys as compared to girls. In addition, children's body composition, as well as their BMI, changes between genders (Rolland-Cachera et al. 1982; Cole et al. 1995; Dietz & Bellizzi 1999; Cole et al. 2000). Therefore, it is conceptually important to estimate separate models by gender. In this analysis, a major aim is to determine whether boys' and girls' risk of overweight are impacted by physical and social neighborhood conditions. We test a model of neighborhood influence on child overweight risk in the effort to identify potential risk and protective factors within children's residential environments. Our results contribute to the emerging literature on environmental predictors of child risk of overweight.

Data

Individual-level data for this analysis were drawn from 2003 to 2004 National Health and Examination Surveys (NHANES). The NHANES is an ongoing survey of the general US population conducted by the National Center for Health Statistics within the Centers for Disease Control and Prevention. NHANES is a cross-sectional survey that uses a stratified, multistage probability design to sample the civilian, noninstitutionalized population residing in the 50 states and the District of Columbia. NHANES participants undergo a survey as well as a medical examination that includes blood work and measured height and weight. The study sample for this paper was 1753 (915 girls and 838 boys) aged 2–11 years. Neighborhood-level data were from a variety of sources, detailed below. Key individual controls were also included in these analyses. Race/ethnicity was self-reported; nonHispanic whites, nonHispanic blacks, and Hispanics were included in the analyses. Child age in years, gender (male vs. female), and household income (11 categories ranging from the lowest level of \$4,999 or below to the highest level of \$75,000 or above) per capita were also included in all models.

Measures

Risk of overweight

The main outcome variable of interest, at risk for overweight status, was classified based on the BMI-for-age and sex percentile defined by the Center for Disease Control (CDC) growth charts (Kuczmarski et al. 2003). Children are considered as being at risk of overweight if their age and gender specific BMIs are greater than the 85th percentile.

Neighborhood context

Structural environmental features of the neighborhood were measured with two variables: neighborhood poverty was measured with a variable from the census that documents the percentage of households in the census tract who are below the poverty line. The poverty

line was determined by the US Census Bureau. Rurality was based on the 2000 Rural–Urban Commuting Area Codes created by the Economic Research Service, United States Department of Agriculture (<http://www.ers.usda.gov/Data/RuralUrbanCommutingAreaCodes/>), where values range from 1 which is a metropolitan area core to 10 which designates rural areas. These 10 codes provide a delineation of metropolitan and nonmetropolitan settlement based on the size and direction of primary commuting flows.

Built environment factors were measured with three variables. Census tract-level long commuting was measured as the percentage of individuals commuting at least 1 h per day to work based on census 2000 summary files 3 (SF3). Neighborhoods with long-commuting times are environments in which adults have more difficulty modeling exercise behavior for children. In addition, two GIS-based measures were constructed. Using the tree canopy data in the 2001 National Land Cover Database, a neighborhood greenery variable was constructed by the percentage of area covered by tree canopy within each 30m pixel. Park accessibility was measured by population-weighted distance (in miles) from the neighborhood centroid to the nearest seven parks. GIS techniques were employed to construct neighborhood greenery and access to parks. Both density and distance were considered in constructing the park accessibility measure. An in-depth description of the method used to construct the park access measure is available elsewhere (Zhang et al. 2011). Model-based multilevel small-area estimation methods were used to generate tract-level obesity prevalence from individual responses from the CDC Behavioral Risk Factor Surveillance System (BRFSS) sample.

Dynamics of social modeling within the neighborhood were operationalized with two separate variables derived from the BRFSS, an annually conducted cross-sectional nationwide telephone survey of Americans' health behaviors (Centers for Disease Control and Prevention 2011). Prevalence of overweight and prevalence of individuals meeting the CDC physical activity recommendations were included to tap weight-related normative environment present in the neighborhood, using data from the 2000 BRFSS. Inclusion of adult weight behavior captures a norm that could likely affect parents who in turn influence their children's activity and diet patterns. The CDC recommends that adults aged from 18 to 64 should participate in at least 20 min of activity per day, and vigorous activity several days per week (Centers for Disease Control and Prevention 2009).

Statistical methods

GIS methods were used to construct neighborhood measures of greenness, park accessibility, prevalence of overweight, and prevalence of individuals meeting the CDC physical activity recommendations. After data construction, child overweight risk was regressed on a set of variables capturing elements of the physical environment, built environment, and social modeling factors. Multilevel regression analyses were performed to account for within-tract dependence (Raudenbush & Bryk 2002). Intraclass correlations (ICC) were presented along with the regression results. Likelihood ratio tests of the ICCs were performed to test the significance of the random effect term in the multilevel models compared with a model fitted without the random effect.

All analyses controlled for age, race/ethnicity, and household income per capita. All neighborhood variables were standardized except for rurality which is an ordinal categorical variable. We present results first for the overall sample then separately for boys and girls.

Results

Table 1 presents descriptive characteristics for the total sample of children aged from 2 to 11 from the NHANES. This table reveals that approximately 34% of the sample is at risk for overweight and the average BMI is about 18. The children live in census tracts where approximately 9% of the residents have over an hour commute to work. Approximately 14% of the census tracts in which the respondents live are covered by green canopy. Residents, on average, live about 5.5 miles away from a park. Children live in neighborhoods where approximately 17% of residents are below the poverty line. As measured by the 2000 rural–urban commuting codes from the census data, children live in census tracts where the majority of the commuting is within the metropolitan area. Children live in census tract neighborhoods where about 22% of residents are overweight. Approximately 21% of the residents in neighborhoods are meeting the CDC recommendation for physical activity.

In terms of individual socio-demographic characteristics, the sample is equally split between boys and girls. Average household income ranges from \$25,000 to \$36,000 among neighborhoods, lower than the national average of \$43,000 in 2003 (US Census 2004). The sample is approximately evenly split across whites, African-Americans, and Hispanics. A small portion of the sample (6%) is represented by the race category “other”. The mean age of the sample children is approximately 6 years old.

Table 2 presents multilevel multivariate estimates of the associations between neighborhood characteristics and child overweight risk. Structural conditions within the neighborhood appear to be important factors associated with childhood overweight. Children living in a census tract with one standard deviation (SD) higher in proportions of residents below the poverty line have a 19% increased odds of being at risk for overweight. Rural community residence is also associated with higher odds of childhood overweight risk. Living in a census tract that is one level higher in rurality is associated with a 29% increased odds for childhood overweight risk. One SD higher in the prevalence of long-commuting residents within the census tract is associated with a 9% increase in child overweight risk. One SD higher in the prevalence of residents who meet the CDC requirements for physical activity corresponds to a 13% decrease in risk of childhood overweight risk.

Several individual characteristics also have significant associations with risk of child overweight. Hispanic children have almost a 50% increased odds of being overweight as compared to white children. Also risk of childhood overweight increases with age, with one additional year in age associated with an 18% increase in risk of overweight.

In gender-specific models, we observe different patterns of associations between neighborhood contexts and risk of overweight across gender (Tables 3 and 4). For girls, there is evidence that living in a census tract with longer commute times translates into a higher risk for overweight. Living in an area where one SD higher proportions of residents commute longer than an hour to or from work is associated with a 13% increase in overweight risk. However, we observe that girls who live in census tracts with one SD higher proportions of overweight residents have a 15% *decrease* in the odds of overweight risk. For boys, there is a different picture that emerges from these results. The only neighborhood characteristic that is significant is rurality. Among boys, living in areas that are more rural is associated with an elevated risk of being overweight. The patterns of higher odds of child overweight for Hispanic children and older children are consistent across gender-specific models.

We conducted alternative modeling analyses that tested for the effects of institutional factors, built environment factors, and social modeling factors separately. This was done as

a sensitivity test to see if individual measures of neighborhood influence were associated with risk of overweight. Results from these supplemental analyses showed similar patterns of association to estimates presented in Tables 2-4.

Discussion

Girls' overweight risk appears to be influenced by three different aspects of neighborhood conditions. First, neighborhood poverty is associated with higher risk of overweight. This suggests that perhaps institutional conditions within neighborhoods may translate into diminished resources needed for neighborhood support of healthy weight. Neighborhoods with diminished economic resources might be locations that lack physical amenities and sense of trust that may influence parents to curtail their daughters' activities outside the home, therefore potentially limiting girls' ability to engage in physical activity. Poor economic resources within the neighborhood may also represent a less-than-optimal food environment both in terms of grocery and restaurant options that could limit the available food choices. Certain populations have less access to affordable, healthy foods and safe locations for physical activity. Evidence also indicates that minority and low-income populations have less access to physical activity facilities and resources, and that traffic and neighborhood safety might inhibit walking (Adler & Stewart 2009). Further research is needed that directly models food choices and exercise patterns for girls in less advantaged neighborhoods to test this potential mechanism.

Girls' overweight risk is also affected by built environment features. We find evidence that living in communities where greater proportion of residents have long commutes to work are settings in which girls are more likely to be overweight. We conjecture that long commuting may be marker for overall time use patterns that might prevent parents from investing time in local play opportunities or to model healthy behaviors related to diet and exercise. Prior research suggests that participation in organized sports has a beneficial effect on children's weight (Romani 2011). These activities might not be as accessible if residential settings are more remotely located and considerable parent time is used in commuting to work. Longer commuting is also a likely proxy for neighborhood mixed land use diversity, an established predictor of exercise and obesity (Smith et al. 2008). Communities that are further removed from key destinations such as employment are more likely to be communities that are primarily residential or rural. The diversity of activities and opportunities for physical activity and diet support may be more limited in these communities. Finally, there might be differences on the part of parents in reacting to residence in disadvantaged communities. Sayer and Dwyer (2011) find gendered perceptions of neighborhood disorder and social control such that girls are more constrained in less-advantaged neighborhood environments, and are particularly discouraged to participate in activities done outside the home. That we also find gender differences in the associations between economic resources and obesity might lend support to Sayer and Dwyer's arguments.

We also find significant associations between living in communities where there are more obese residents and decreases in the risk of childhood overweight, but only among girls. This is an intriguing finding and suggests social modeling dynamics such that presence of obese neighbors confers almost a cautionary effect on girls. Prior scholarship has argued for the opposite effect suggesting that in communities with more obesity, there is diminished stigma of obesity (Puhl & Heuer 2009). However, this issue has been rarely examined among children. These results suggest that perhaps some parents have a heightened awareness of the issue of obesity in these neighborhoods and increase their efforts to promote physical activity and healthy diet choices particularly for girls. This finding underscores the need for further investigation of the potential for differential effects of social modeling for boys and girls.

The one feature of the neighborhood environment that has a significant association with risk of overweight among boys is living in a more rural community. Higher rates of obesity among rural men and women have been observed in a variety of data (Jackson et al. 2005; Patterson et al. 2004; Olsen et al. 2008). Mechanisms of lack of health education, reduced access to healthy foods (Singh et al. 2010) and decreased involvement in physical activity (Liu et al. 2007; Moore et al. 2008) have been identified. However, research is still emerging on how salient these issues are for children and whether there are differences by gender. These estimates suggest that perhaps boys are particularly vulnerable in rural settings. Our findings are consistent with findings obtained from a sample of first graders in rural Wyoming that boys are more likely to experience rapid weight gain in rural areas as compared to girls (Smith et al. 2008). Sayer and Dwyer's (2011) work suggests that boys spend more time in playing sports and engaging in computer activities. Our results suggest that boys who live in rural environments might be prevented from engaging in sport activities, because of the rural nature of their neighborhoods and perhaps are instead choosing more sedentary activities such as TV viewing and computer gaming.

Boys and girls may have different physical activity patterns. Evidence from studies of adults shows that women tend to be more responsive to neighborhood contexts than men (Authors 2007), which is different than the pattern we found for youths here. This discrepancy may suggest that gender differential neighborhood effects vary across different stages of life courses and are worth further exploring. However, our current analyses do not directly model the effects of increased screen time in rural areas among boys. Differing physical activity and sedentary patterns for girls and boys in rural settings is an important avenue for future research using these data. Parents might place fewer restrictions on boys' activities outside of the home based on perceived safety risks of the neighborhood environment. This dynamic might lead to a differing pattern of neighborhood amenities being more salient for boys as compared to girls. Moreover, boys and girls may differ in the patterns of time use and usual activities. Girls generally spend less time than boys in sports and electronic games and more time studying, doing housework, and in unstructured leisure with friends, activities that presage adult differences in time use (Bianchi & Robinson 1997; Larson & Verma 1999). Recent evidence (Sayer & Dwyer 2011) suggests that there may be gender differences in time use associated with neighborhood variation. Boys might be more likely engaged in sports but also sedentary activities such as television watching as compared to girls. Thus, features of the built environment such as distance to parks might impact boys' activities more than girls, and perhaps leading the differences in body weight.

There are some limitations to these analyses that should be noted here. First, these analyses are based on cross sectional data so that strong causality claims cannot be placed on the findings discussed. It would be important to test for the influence of the variables in our model of neighborhood influence using longitudinal data. Unfortunately, the data we use for these analyses, the national health and nutrition examination survey is a repeated cross-sectional data and not panel data. However, the NHANES brings other strengths to the issue such as a large nationally representative sample and child BMI is calculated from reliable clinically measured weight and height. Second, there is nonrandom selection of individuals into residential settings. Research linking community characteristics to individual outcomes must contend with the potential existence of selection bias in the interpretation of results. It might well be that families select themselves into residential opportunities that reflect preexisting motivations and personal characteristics that might also influence the outcome of interest, child overweight. However, a body of research is beginning to emerge that suggests that nonrandom selection might be present in the estimation of neighborhood built environment factors on individual BMI but that causation is also present (Authors 2010).

Overall, these analyses break new ground in better understanding the ways in which institutional neighborhood factors, built environment factors, and social modeling dynamics might influence risk of childhood overweight. Results reported here rely on a national sample using GISs modeling to create variables measuring these characteristics. Policy-makers should take note of the need to consider boys and girls separately in thinking about the design and modification of communities and the associated risk for energy balance decisions. The current analysis adds to the literature in a number of ways. First, we use nationally representative data on child weight that is the product of both parental report and clinical measurement. We link a variety of data sources to the main data at the census tract level, an improvement on other research that relies on ZIP Code or larger levels of aggregated data. Second, we consider a model of neighborhood influence that simultaneously tests for both institutional factors and social modeling processes. Many prior investigations have relied on guiding models that test for the influence of either built environment factors or social factors. Rarely does research on neighborhood effects on child obesity consider both equally important aspects of community influence. Finally, we address the question of whether neighborhood factors have different patterns of influence depending on the gender of the child. Results from this research help to refine and extend the knowledge base on the potential role of the larger social environment on children's risk of overweight. In doing so, results inform policy efforts to interdict the growing trend of overweight children in the USA.

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Table 1

Sample descriptive characteristics.

	Mean	SD
Child BMI	17.9	3.9
Children who are overweight (%)	34.0	4.8
% long-commuting residents ^a	9	7.9
% green space	14.1	16.2
Distance to parks (mile)	5.5	13.67
Prevalence of residents meeting CDC PA recommendations (%)	21.1	3.3
Prevalence of overweight (%)	22.1	4.4
Residents in poverty (%)	17	0.11
Rurality (1–10)	1.85	2.02
Male (%)	48	5.0
White (%)	28	4.5
Black (%)	33	4.7
Hispanic (%)	33	4.7
Other race (%)	6	2.4
Age (years)	6.09	2.97

Source: 2003–2004 national health and nutrition examination survey merged with a number of place-based data-sets including the 2000 census, 2002 BRFSS, and GIS-based park access and green area data.

^a Long-commuting residents are defined as those who spend at least an hour commuting to work every day.

Table 2Risk of overweight among children aged 2–11 years, NHANES 2003–2004 ($N = 1621$).

	Odds ratios	95% CI	
<i>Neighborhood characteristic</i>			
% residents in poverty	1.19**	1.02	1.39
Rurality	1.26*	0.98	1.62
% long-commuting residents	1.09*	0.98	1.22
% green space	1.07	0.88	1.30
Distance to parks (mile)	0.97	0.80	1.19
Prevalence of physical activity	0.88**	0.78	0.99
Prevalence of overweight	0.91	0.79	1.05
<i>Individual characteristic</i>			
Male	0.97	0.78	1.21
Income per capita	1.11	0.96	1.30
Black	1.04	0.71	1.52
Hispanic	1.50**	1.06	2.13
Other race	0.89	0.52	1.53
Age	1.18***	1.14	1.23
ρ (intraclass correlation)	0.07		
Likelihood ratio test of $\rho = 0$	6.66**		

Note: Cell entries represent odds ratios and associated 95% confidence intervals. Source: 2003–2004 national health and nutrition examination survey.

* $p < 0.10$;

** $p < 0.05$;

*** $p < 0.01$ (two-tailed tests).

Table 3Risk of overweight among boys ages 2–11, NHANES 2003–2004 ($N = 766$).

	Model II	95% CI	
<i>Neighborhood characteristic</i>			
% residents in poverty	1.12	0.87	1.43
Rurality	1.42 *	0.94	2.14
% long-commuting residents	1.05	0.89	1.24
% green space	0.96	0.71	1.29
Distance to parks (mile)	0.95	0.70	1.28
Prevalence of physical activity	0.89	0.74	1.07
Prevalence of overweight	0.99	0.79	1.23
<i>Individual characteristic</i>			
Income per capita	1.12	0.88	1.42
Black	0.73	0.40	1.33
Hispanic	1.61 *	0.92	2.82
Other race	1.00	0.46	2.16
Age	1.20 ***	1.12	1.27
ρ (intraclass correlation)	0.15		
Likelihood ratio test of $\rho = 0$	6.16 **		

Source: 2003–2004 national health and nutrition examination survey. Cell entries represent odds ratios and associated 95% confidence intervals.

* $p < 0.10$;** $p < 0.05$;*** $p < 0.01$ (two-tailed tests).

Table 4Risk of overweight among girls ages 2–11, NHANES 2003–2004 ($N = 845$).

	Odds ratios	95% CI	
<i>Neighborhood characteristic</i>			
% residents in poverty	1.24**	1.01	1.52
Rurality	1.70	0.87	1.57
% long-commuting residents	1.13*	0.98	1.3
% green space	1.15	0.91	1.47
Distance to parks (mile)	0.97	0.78	1.21
Prevalence of physical activity	0.88	0.76	1.03
Prevalence of overweight	0.85*	0.70	1.02
<i>Individual characteristic</i>			
Income per capita	1.16	0.96	1.42
Black	1.42	0.86	2.33
Hispanic	1.51*	0.96	2.37
Other race	0.87	0.39	1.93
Age	1.17	1.11	1.24
ρ (intraclass correlation)	0.06		
Likelihood ratio test of $\rho = 0$	1.06		

Note: Cell entries represent odds ratios and associated 95% confidence intervals. Source: 2003–2004 national health and nutrition examination survey.

* $p < 0.10$;

** $p < 0.05$;

*** $p < 0.01$ (two-tailed tests).