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Physical characteristics of the environment and BMI of young urban children and their mothers☆,,☆ ☆

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Abstract

The study examined whether characteristics of the urban physical environment are associated with child and maternal body mass index (BMI) in a sample of 3 year-old children and their mothers from 18 US cities (*N*=1997 dyads). BMI was determined based on measured height and weight. Characteristics of the interior and exterior physical environment, assessed and rated by trained interviewers, were related to child BMI at age 3 and to their mother's BMI. Negative aspects of the physical environment were more strongly related to maternal BMI among whites than among African–Americans or Hispanics.

Keywords

Physical environment; Child; Obesity; Race/ethnicity; Disparities; Maternal weight

1. Introduction

The notion that the physical environment can be 'obesogenic' (Booth et al., 2005; Egger and Swinburn, 1997; Lopez and Hynes, 2006; Rundle et al., 2007) has grown in acceptance over the last decade. Despite some evidence that the physical environment is related to obesity early in life (Scott et al., 2007; Spence et al., 2008; Timperio et al., 2005a), most of the work has focused on adults. Urban design factors, land use, availability of public transportation, and physical activity facilities within a certain area can directly influence physical activity and healthy eating. Several studies support the notion that certain aspects of the physical environment – e.g., walkability (Giles-Corti et al., 2003), urban sprawl (Ewing et al., 2003)

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or land use mix (Frank et al., 2004) – are associated with obesity. Results, however, are mixed (Brug et al., 2006) and underlying mechanisms remain poorly understood (Srinivasan et al., 2003). Current understanding about the role of food availability in the development of obesity illustrates the complexity of the issue. While lower rates of obesity are found among individuals who shop (Morland et al., 2006) or live (Rundle et al., 2009) in areas with more healthy food stores (such as supermarkets compared convenience stores), the actual impact of large-scale retail interventions on obesity has not been established (Cummins et al., 2005a, 2005b). There is increasing recognition that the role of the physical environment on any health behavior can be properly understood only if considered in relation to other components of the environment, which include the multiple spaces an individual may relate to (e.g., school and home) as well as variations in the timing of such interactions (daily, weekly or even throughout one's lifetime) (Cummins et al., 2007).

The influence of the physical environment on children's weight has been addressed less frequently than adults and results are also inconsistent (Dunton et al., 2009; Franzini et al., 2009; Papas et al., 2007; Sallis and Glanz, 2006) as compared to studies of adults. In a national longitudinal sample, researchers found a positive cross-sectional relationship between urban sprawl and obesity in children, however, longitudinal findings were not statistically significant (Ewing et al., 2006). Some studies have examined the association of parental perceptions of the environment and child obesity risk. Parental perception of the physical environment of neighborhoods as deteriorated was related to obesity in children (Timperio et al., 2005b). Parental perception of neighborhood safety was associated with overweight at age 7 in one study (Lumeng et al., 2006), but not with overweight in children at 3 years, based on data derived from to the Fragile Families and Child Wellbeing Study (Burdette and Whitaker, 2005). A key issue when examining the relationship between the physical environment and obesity risk in children is distinguishing which aspects of the environment may be relevant and at what developmental stage. In general terms one would expect a more consistent relationship between the physical neighborhood environment and obesity promoting behaviors in older than in younger children. As it pertains to toddlers, for example, parental perceptions of urban sprawl may be a less important determinant of a toddler's behaviors and obesity risk than the interior of their homes and buildings. Inasmuch as the home is the primary environment for toddlers, elucidation of the link between these more immediate aspects of the physical environment and early obesity could improve understanding of key mechanisms for this age group.

Racial and ethnic minorities tend to live in neighborhoods with unequal distribution of the resources that promote healthy behaviors. These inequities put residents at a disadvantage in achieving dietary and physical activity health recommendations. Poor neighborhoods and neighborhoods with a high percentage of racial and ethnic minorities are less likely to have recreational facilities (Gordon-Larsen et al., 2006; Powell et al., 2006). Such disparities in the distribution of recreational facilities appear to be related to lower levels of physical activity and higher rates of obesity among minority adolescents (Gordon-Larsen et al., 2006). Similar patterns exist in the distribution of retail establishments that sell healthy foods (Gordon-Larsen et al., 2006). Evidence shows that the presence of more supermarkets in a neighborhood can influence the consumption of fruits and vegetables particularly among its minority residents (Morland et al., 2006).

The extent at which the physical environment may be related to the weight status of young children and their mothers has not been established. If such a relationship exists, it would be expected to vary across different racial/ethnic groups given what is known about the differential distribution of physical environmental characteristics. Because other socio-demographic characteristics, such as parental educational level or family income, may

actually be the sole factors explaining the relationship between the physical environment and childhood obesity, they also need to be considered.

Our secondary analysis of data from an urban mostly minority and low-income sample – derived from the Fragile Families Study (Reichman et al., 2001) – focuses on the association between the conditions of the physical environment with child and maternal body mass index (BMI). Our analysis advances the existing literature by examining how the BMI of very young children (36 months) and their mothers is related to multiple aspects of the physical environment and examines whether such relationships vary across racial/ethnic groups. Our investigation is performed accounting for other socioeconomic factors present in the lives of these vulnerable families.

2. Methods

2.1. Study design and participants

The Fragile Families and Child Wellbeing Study is an ongoing longitudinal study initiated of a US national sample representative of all births from non-married couples in 18 selected cities with more than 200,000 inhabitants between 1998 and 2000. The study oversampled births to unmarried couples in a ratio of 3 to 1 births to married couples, and, when weighted, the data are representative of non-marital births in large US cities (Reichman et al., 2001).

The study protocol consists of telephone interviews with both mothers and fathers at birth and again when children were ages one, three, and five years, as well as in-home assessments of children and their home environments at ages three and five. The first three waves of data are publicly available. The analyses presented herein focus on the in-home assessments (N=2119 mother–child dyads) conducted in the third wave, when children were approximately 36 months. Only children for whom the in-home interview included interviewer observations of the conditions of the physical environment and measured height and weight with plausible values (N=1977 dyads) are included in the analysis. Specific information from the previous waves (e.g., birth weight, breastfeeding) are used when appropriate.

The Fragile Families and Child Wellbeing Study was approved by the institutional review boards of Princeton University (Princeton, New Jersey) and the 75 participating hospitals. The current analysis was also approved by the New York State Psychiatric Institute Institutional Review Board.

3. Measures

3.1. Body mass index (BMI)

During the in-home assessment, when children were about 3 years old, trained interviewers measured height and weight with participants wearing light clothing and no shoes. An electronic scale (SECA 840 Bella Digital Scale, Hanover, MD) was used to measure weight and a portable stadiometer (SECA 214 Road Rod Stadiometer) for height. Body mass index (BMI, kg/m^2), a measure of relative weight, was calculated from measured height and weight. The 2000 CDC growth reference was used to determine an age- and gender-specific BMI z-score for each child. Definitions of child overweight (85th–95th percentile BMI) and obesity (>95th percentile) reflect current recommendations (Kuczmarski et al., 2002). For children, BMI-z scores, a measure of child relative weight, were used in statistical analyses as a continuous variable. For mothers, weight and height were also measured, except for 195 mothers who self-reported their weight and 122 their height (reasons for self-report were pregnancy, refusal to be measured or exceeded the scales capacity). In the case of pregnant

mothers (n=148), pre-pregnancy weight was reported. For mothers, obesity was defined as a BMI ≥30 and overweight as BMI ≥25 but less than 30. BMI was used in statistical analyses as a continuous variable.

3.2. Physical environment

During the third study wave, when children were 36 months old, trained interviewers completed an observation checklist, immediately after finishing in-home interviews, to gather information about the interior and exterior surroundings of the household. We retained for analysis only items with less than 10% missing values (6 out of 28 items were excluded). The interior physical environment was evaluated using 8 items regarding the integrity and organization of the household. The assessment of the exterior physical environment was made using 12 items that addressed the conditions of the building and of the streets within 100 yards the household.

Within the household *interior physical environment*, 4 items relate to *household interior decay* (broken or cracked windows, walls, ceiling or floor), 4 to *household interior disorganization* (darkness, crowding, cluttering, dirtiness). To assess the *exterior physical environment*, 4 items address the *surrounding area deterioration* (e.g. graffiti and vacant, abandoned or boarded-up buildings on the household's block or within 100 yards) and 8 items the *building deterioration* (e.g. broken glass/toys in the environment immediately outside of the building; peeling paint crumbling/damaged walls in the exterior of the building).

We performed a confirmatory factor analysis (CFA) of the selected items using MPlus software (Muthén and Muthén, 2007) with mean and variance-adjusted weighted least-squares method (wlsmv) to test the extent to which the four-factor structure we assumed for the physical environment items was empirically supported. The following criteria were used to assess model fit: comparative fit index (*CFI*) >0.90 acceptable, >0.95 excellent (Bentler, 1990; Bentler and Bonett, 1980; Tabachnick and Fidell, 2001), and root mean square error of approximation (*RMSEA*) <0.08 acceptable, <0.05 excellent (Browne and Cudeck, 1993). Given the large number of degrees of freedom in the data, chi-square was not used as a criterion for fit because of its sensitivity to sample size. The chi-square value will always increase when sample size is over 200, resulting in a highly significant chi-square/df ratio even when there is a good fit (Kelloway, 1998). The factor structure tested provided the following results: *CFI*=0.948; *RMSEA*=0.060 indicating that the data are fitted well by the assumed factors. Factor loadings were greater than 0.795 for *household interior decay* items, greater than 0.576 for items related to *household interior disorganization*, greater than 0.801 for the *surrounding area deterioration items* and greater than 0.731 for *building deterioration* items.

3.3. Additional correlates

Child characteristics considered included child age, gender, birth weight status (low birth defined as less than 2.5 kg) and race/ethnicity. Child race/ethnicity was defined based on the mother's information about her own race/ethnicity. Four categories were defined: (1) non-Hispanic White, (2) non-Hispanic Black, (3) Hispanic (any race), and (4) Other race (non-Hispanic). Demographic correlates include maternal age, race/ethnicity and level of education (9 levels, ranging from 1=no formal education to 9=completed graduate school), household composition (mother living with the child's father or a partner), annual family income, and household size; all information was obtained in the in-home interview when children were 36 months, on average.

3.4. Data analysis

We used descriptive statistics to examine the distribution of physical environment characteristics, child BMI *z*-score and maternal BMI. Multiple linear regression analyses examined the association between the physical environment and child BMI *z*-score at 36 months (dependent variable), as well as with maternal BMI (dependent variable), adjusting for relevant correlates. Initially, unadjusted models were estimated, one for each aspect of the physical environment as the only independent variable and with either maternal BMI or child BMI *z*-score as the dependent variable. Characteristics frequently associated with obesity according to the available literature were also included in the model to determine if the physical environment would be associated with child weight or maternal weight, independently of other socioeconomic family factors and, for the models of child BMI *z*-score, of individual child factors as well. Once the final model was defined, we tested the significance of the interaction between each physical environment dimension and race/ethnicity. Results were stratified by race/ethnicity when the interaction term was statistically significant. The alpha level for all analyses was 0.05. Statistical analyses were conducted using SAS software version 9.1 (SAS Institute Inc., 2003).

4. Results

Table 1 shows the distribution of child and mother BMI, and selected demographic variables. Obesity was present in 16.5% of children at age 3 and 41.0% of their mothers. Family income and maternal educational level were low, and 40% of the children were living with their mothers without a partner. Table 2 displays the interior and exterior physical environment items. The least common characteristic of the physical environment was the presence of holes on the floor in the interior of the house (2.1% of the households), and darkness inside of the house was the most frequent (24.5%).

Table 3 provides the regression coefficients representing the association between different dimensions of the physical environment and child BMI *z*-score. For children, decay of the interior environment and deterioration of the exterior areas (surroundings and building) were related to BMI *z*-score. Notably, these associations were still statistically significant after statistical control for potentially relevant socio-demographic factors. To ascertain whether the association between characteristics of physical environment and BMI differed by race/ethnicity, interaction terms for each physical environment variable and race/ethnicity were tested in separate models. None of the interaction terms were significant (*p*-values ranged from 0.14 to 0.50), suggesting the associations between physical environmental variables and child BMI *z*-score did not differ by race/ethnicity and therefore further stratified analysis was not conducted.

For mothers, physical conditions of all dimensions of the interior and exterior environments were related to maternal BMI. In contrast to the results for children, interaction terms for the physical environment variables and race/ethnicity were statistically significant, suggesting the association between characteristics of the physical environment and maternal BMI differ by racial/ethnic group (Table 4). Characteristics of the physical environment were strongly associated with maternal BMI among White, non-Hispanic and Other, non-Hispanic mothers. Among Black, non-Hispanic mothers, the associations were weaker, but still statistically significant. None of the associations between physical environment variables and maternal BMI were significant for Hispanic mothers.

5. Discussion

We identified specific characteristics of the household interior and exterior physical environments that are positively associated cross-sectionally with measures of relative

weight in children and their mothers. Specifically, decay of the interior home environment and deterioration of building and surrounding areas were related to child BMI *z*-score. Whereas we detected no variation in the reported relationships by child race/ethnicity, associations between physical environment and maternal BMI were found to differ by race/ethnicity. The associations we observed were stronger among mothers of White and Other race/ethnicity as compared to mothers of Black race/ethnicity; associations not present among Hispanic mothers.

The mechanisms by which attributes of the interior and exterior physical environment are to be linked to higher weight status in mothers or children have not been established. Nor do we know how these characteristics of the physical environment would, in themselves, facilitate or hinder physical activity and/or healthful eating, key modifiable determinants of weight status. Socioeconomic disadvantage (such as single parenthood, low maternal education level, or low family income) are prevalent in this sample and known to be related to obesity (Shrewsbury and Wardle, 2008; Singh et al., 2008). Our results support the notion that the quality of the physical environment could have an independent impact on childhood obesity. Fullilove and Fullilove III (2000) that three important dimensions underly the connection between housing and health. Housing may be viewed (a) as fulfilling a fundamental necessity, (b) in relation to other housing units, creating a “physical infrastructure for group life”, and (c) in its psychological dimension, as “home,”, a central point for the individual’s orientation in time and space. Within this framework, deterioration of the physical housing environment may relate to weight status through distinct pathways. For example, decay in the household interior may impair individual’s capacity to store and prepare food. It may also limit the movement of toddlers within their homes. The feeling of danger associated with the deterioration of the physical environment can result in breaking connections with the larger community, impairing mobility and therefore limiting access to nutritious food and opportunities for recreation. Psychological disengagement or depression may also manifest in relation to the deterioration of the physical environment (Galea et al., 2005) and may lead to excessive reliance on unhealthy food and lack of motivation for recreation.

Several of the pathways that relate the environment and obesity may be directional, adding further complexity. Thus, the dynamic relationships between individual behaviors and their environments may also explain the association between the deterioration of the physical environment and health outcomes, in this case, obesity. In trying to understand the relationship between “broken windows” (an index of neighborhood deterioration) and risk of gonorrhea, Cohen et al. (2000) postulate several possible explanations, operating at distinct levels: at the individual-level, those individuals who are most likely to contribute to the deterioration of their environment are also likely not to adopt healthy behaviors; at the structural-level, deteriorated environments would contribute to unhealthy behaviors, in that the appearance of the environment may convey specific messages which regulate behaviors (Podorefsky et al., 2001).

The impact of the physical environment on a 3-year old’s weight status would be expected to largely reflect maternal behaviors, inasmuch as the dietary and physical activity patterns of young children are directly related to parental behaviors (Birch and Davison, 2001; Cutting et al., 1999). For infants and toddlers, breast or formula feeding may still be the most frequent feeding option and, particularly before the first year of life, physical activity is limited. Indeed, post hoc analyses indicates that when the child models displayed in Table 3 are also adjusted by maternal BMI, the regression coefficients are substantially reduced and no longer statistically significant (for housing decay B(SE)=0.07(0.05) p=0.1419; for surrounding area deterioration B(SE)=0.08(0.05) p=0.084; for building deterioration B(SE)=0.08(0.06) p=0.1571). This pattern of results is compatible with the idea that for

young children, a deteriorated physical environment would impact children's BMI through its influence of maternal BMI and possibly on other (unmeasured) obesity-related behaviors.

The relationships between the aspects of the physical environment we found to be related to child weight status do not appear to vary by race/ethnicity. Recently, Kimbro et al. (2007) reported clear racial/ethnic differences in relative weight in the Fragile Families sample when the children were as young as three; these disparities were not explained by a broad range of factors. Interestingly, among adult women, we observed variations in the relationships between the physical environment and BMI across racial/ethnic groups. The racial/ethnic specific pattern of associations that emerges is similar to the pattern of association between socioeconomic status and obesity that has been observed recently in the US, where within Whites a strong inverse association between socioeconomic level and overweight is observed (Wang and Zhang, 2006). In addition, a recent study conducted in New York City, reported that associations between the built environment and BMI were stronger for advantaged compared to disadvantaged individuals or areas (Lovasi et al., 2009). One possible explanation is that obesity among disadvantaged populations, including those defined by race/ethnicity, is determined by an accumulation of risk factors, and no single factor is clearly identifiable.

The investigation of the physical environment as an important determinant of obesity in general, and childhood obesity in particular, is an emergent area of interest. Several issues, however, are still unresolved. For example, there is no consensus in the literature about how aspects of the physical environment should be categorized, or which domains are most important. In this context, we elected to present our results for physical environment dimensions, grouped under conceptually defined categories for which empirical evidence (derived from confirmatory factor analysis) was also available. This strategy is not free of problems, such as the high correlation among dimensions, so that additional studies are necessary to verify our findings.

Study limitations should be considered carefully in the interpretation of our findings. First, we were only able to include in our analysis children whose height and weight were measured during an in-home interview at age 3, and for whom interviewer ratings of the physical environment were available. Therefore, selective loss to follow-up and/or compliance with specific procedures may have occurred, affecting the generalizability of our conclusions. Second, we were only able to examine specific aspects of the physical environment considered at the individual level, as the low level of sample clustering in the sample does not allow consideration of group effects. Ideally the impact of the physical environment should be observed at the community or neighborhood level. The Fragile Families study sampling design, however, given its national scope and initial sampling through hospitals, does not yield a sample clustered at the small area level (which could be used as proxies for communities or neighborhoods). A third limitation is that, despite its longitudinal design, the large proportion of missing information led us to limit our analyses to cross-sectional data collected at age 3, when information about both physical environment and weight were available for most of the sample. Finally, future studies are needed to establish whether the associations described here are present among older children or in less vulnerable populations.

These limitations are offset to some extent by several strengths. These include the use of large national, urban sample at risk for obesity due to low socioeconomic status and large proportion of minority subjects. Furthermore, trained interviewers performed the ratings of the physical environment, avoiding the potential for reporting bias.

From a public health perspective, our findings provide valuable information about the ways in which aspects of the physical environment, particularly the household environment and immediate/surrounding buildings, relate to the BMI of young children and of their mothers. We have identified important racial/ethnic differences in the relationship between the physical environment and weight, which, if confirmed, could inform policy so it could be tailored to meet the needs of population subgroups at greatest risk.

As a modifiable, clearly policy-related factor that may promote obesity, the physical environment represents a promising area of investigation for those interested in addressing the obesity epidemic. Ultimately, successful intervention and prevention of obesity will require identification of specific intervening mechanisms and will focus on the influences which contribute to the manifestation of these intervening mechanisms within specific groups (Link and Phelan, 1995). Cumulative evidence on the contribution of the physical environment to the development of obesity will put us in a better place to propose changes in policies related to physical environments that would translate into increases in physical activity, access to healthy foods and ultimately lower obesity rates in disadvantaged communities.

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Table 1

Sample characteristics: Fragile Families Study (*N*=1977 dyads).

Weight status	
Child (%)	
<85th percentile BMI (not overweight/obese)	66.0
85th to 95th percentile BMI (overweight)	17.5
≥95th BMI (obese)	16.5
Mother (%)	
BMI <25 (not overweight/obese)	31.6
BMI 25–30 (overweight)	27.4
BMI ≥30 (obese)	41.0
Child individual factors	
Child age (mo) [*mean*(*SD*)]	35.8 (2.5)
Girls (%)	47.7
Child race/ethnicity (%)	
Hispanic	23.3
Black, not Hispanic	55.0
White, not Hispanic	18.5
Others, not Hispanic	3.2
Low birth weight[a] (%)	9.5
Family factors	
Maternal age (y) [*mean*(*SD*)]	27.9 (5.9)
Family size (# persons in household) [*mean*(*SD*)]	4.4 (1.6)
Mother not living with child's father or partner (%)	40.3
Level of maternal education (*y*) [*mean*(*SD*)]	4.6 (1.7)
Annual family income [*mean*(*SD*)]	$31,339 (3,658)

[a] <2500 g.

Table 2

Physical environment in the Fragile Families Study (*N*=1977 dyads).

	N	%
Interior areas		
Decay		
Broken windows or cracked windowpanes	108	5.97
Open cracks or holes in walls or ceiling	134	7.22
Holes on the floor	38	2.06
Broken plaster or peeling paint (over 1 sq foot)	166	8.92
Disorganization		
Darkness	469	24.49
Crowded	376	19.58
Cluttered rooms	428	22.51
Dirty rooms	406	21.25
Exterior areas		
Surrounding area deterioration		
Garbage, litter or broken glass in the street or road, on the sideways or in yards	280	4.9
Condition of buildings on the block or within 100 yards:		
General condition	294	5.07
Graffitti	80	4.24
Vacant, abandoned or boarded-up buildings	194	10.37
Building deterioration		
Environment immediately outside of the house has:		
Broken steps	193	10.05
Broken glass/toys	237	12.31
Large ditches	65	3.39
Alcohol/drug paraphernalia	98	5.23
Strewn garbage/litter	398	20.2
Exterior of the building has:		
Peeling paint	412	21.54
Crumbling/damaged walls	165	8.73
Broken/cracked windows	121	6.48

Table 3

Physical environment and child BMI *z*-score: results of multiple regression analyses.

	Child BMI *z*-score		
	B	**S.E.**	***p* value**
Models with main effects only			
Interior areas			
Decay	0.10	0.046	0.0246
Disorganization	0.10	0.062	0.1112
Exterior areas			
Surrounding area deterioration	0.12	0.044	0.0067
Building deterioration	0.13	0.055	0.0160

All models are adjusted by age, child gender, race/ethnicity, birth weight, maternal education, family composition, income and size. Interaction terms between race/ethnicity and physical environment were not statistically significant.

Table 4

Physical environment and maternal BMI: results of multiple regression analyses.

	Maternal BMI														
	All racial/ethnic groups			Hispanic			Black, not Hispanic			White, not Hispanic			Other, not Hispanic		
	B	S.E.	*p* value	B	S.E.	*p* value	B	S.E.	*p* value	B	S.E.	*p* value	B	S.E.	*p* value
Interior areas															
Decay	1.09	0.28	0.0001	0.33	0.59	0.5815	0.83	0.38	0.0304	3.01	0.70	<0.0001	3.02	1.26	0.0208
Disorganization	1.44	0.38	0.0002	0.75	0.84	0.3735	1.12	0.51	0.0298	2.76	0.89	0.0022	5.00	1.79	0.0076
Exterior areas															
Surrounding area deterioration	0.86	0.28	0.0019	0.40	0.60	0.5002	0.61	0.36	0.0883	2.22	0.73	0.0026	3.19	1.40	0.0267
Building deterioration	1.41	0.34	<0.0001	0.39	0.73	0.5920	1.15	0.45	0.0111	3.45	0.84	<0.0001	3.79	1.62	0.0238

All models are adjusted by age, race/ethnicity (except stratified models), family composition, income, size, and maternal education.