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Fast-Food Restaurants, Park Access, and Insulin Resistance Among Hispanic Youth

Stephanie Hsieh, PhD, Ann C. Klassen, PhD, Frank C. Curriero, PhD, Laura E. Caulfield, PhD, Lawrence J. Cheskin, MD, Jaimie N. Davis, PhD, Michael I. Goran, MD, Marc J. Weigensberg, MD, Donna Spruijt-Metz, PhD

Background: Evidence of associations between the built environment and obesity risk has been steadily building, yet few studies have focused on the relationship between the built environment and aspects of metabolism related to obesity's most tightly linked comorbidity, type 2 diabetes.

Purpose: To examine the relationship between aspects of the neighborhood built environment and insulin resistance using accurate laboratory measures to account for fat distribution and adiposity.

Methods: Data on 453 Hispanic youth (aged 8–18 years) from 2001 to 2011 were paired with neighborhood built environment and 2000 Census data. Analyses were conducted in 2011. Walking-distance buffers were built around participants' residential locations. Body composition and fat distribution were assessed using dual x-ray absorptiometry and waist circumference. Variables for park space, food access, walkability, and neighborhood sociocultural aspects were entered into a multivariate regression model predicting insulin resistance as determined by the homeostasis model assessment.

Results: Independent of obesity measures, greater fast-food restaurant density was associated with higher insulin resistance. Increased park space and neighborhood linguistic isolation were associated with lower insulin resistance among boys. Among girls, park space was associated with lower insulin resistance, but greater neighborhood linguistic isolation was associated with higher insulin resistance. A significant interaction between waist circumference and neighborhood linguistic isolation indicated that the negative association between neighborhood linguistic isolation and insulin resistance diminished with increased waist circumference.

Conclusions: Reducing access to fast food and increasing public park space may be valuable to addressing insulin resistance and type 2 diabetes, but effects may vary by gender.
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Introduction

Evidence of a relationship between the built environment and obesity risk has been steadily building. Research on the neighborhood food environment has shown that access to healthier foods is associated with lower obesity risk.[1–4] Access to convenience stores[5,6] and fast-food restaurants[7–9] is associated with limited food choices and increased risk of obesity. Policy intervention and debate has focused on national fast-food chain restaurants.[10–12]

Relationships between increasing neighborhood walkability and park access, and increases in physical activity[13–17] and reduced obesity risk[18–21] have been well documented. Type 2 diabetes is the most tightly linked comorbidity of obesity,[22,23] yet little evidence exists relating the built environment and type 2 diabetes.[5,24–26]

From the Department of Health, Behavior and Society (Hsieh, Klassen, Cheskin), Department of Environmental Health Sciences (Curriero), Department of Biostatistics (Curriero), and Department of International Health (Caulfield), Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland; Department of Community Health and Prevention (Klassen), Drexel University School of Public Health, Drexel University, Philadelphia, Pennsylvania; Department of Nutritional Sciences (Davis), University of Texas, Austin, Texas; and the Department of Pediatrics (Goran, Weigensberg), Department of Preventive Medicine (Goran, Spruijt-Metz), and Department of Physiology & Biophysics (Goran), Keck School of Medicine, University of Southern California, Los Angeles, California

Address correspondence to: Stephanie Hsieh, PhD, Department of Health, Behavior and Society, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, 624 N. Broadway, Rm. 263, Baltimore, MD 21205. E-mail: shsieh@jhsph.edu.

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Insulin resistance (IR) plays a major role in the development of type 2 diabetes.[27] IR is calculated from fasting serum glucose and insulin levels using the homeostasis model assessment (HOMA), a measure developed for large-scale studies that is a valid surrogate of the gold standard glucose clamp method.[28,29] The current study is the first to examine the relationship between aspects of the neighborhood built environment and IR, while accounting for adiposity using an accurate measure of body fat.

This analysis was conducted on a sample of overweight and obese Hispanic youth, a population at particularly high risk that deserves specific attention. They are more likely to be overweight or obese than their white counterparts, and also more likely to be insulin resistant.[30–32] Hispanic youth are also at higher risk of living in low-SES neighborhoods with inadequate infrastructure, which are associated with reduced access to recreational facilities or healthy food resources.

Although Hispanic ethnicity itself may not be an independent contributor to obesity or diabetes,[33,34] Hispanic populations are often immersed in a low-SES context,[35] which increases risk for obesity and related metabolic health outcomes.[24,36–38] In addition, acculturation may also play a role in metabolic risk.[39–41] The size and direction of associations between acculturation and metabolism have not been clearly established.[42–45]

Aims

This study utilized pre-existing data from research conducted at the University of Southern California Childhood Obesity Research Center (USC CORC) linked to a database of food and physical activity environment characteristics, and neighborhood sociocultural aspects. The food environment was characterized by the density of fast-food restaurants and convenience store access. The physical activity environment was characterized by acres of park space.

Five hypotheses were investigated through a series of regression analyses: (1) increased access to fast-food restaurants would be associated with increased IR, (2) increased access to convenience stores would be associated with increased IR, (3) increased park access would be associated with decreased IR, (4) increased walkability would be associated with decreased IR, and (5) neighborhood-level acculturation would be associated with increased IR.

Methods

Participant Recruitment

Six studies investigating determinants of metabolic health among overweight and obese Hispanic youth from the USC CORC contributed participant data to this analysis.[46–51] Criteria for inclusion in the current analysis were: (1) Hispanic ethnicity, (2) age- and gender-specific BMI ≥85th percentile, (3) no previous major illness, including type 1 or 2 diabetes, no medications, or conditions known to influence body composition, insulin action, or insulin secretion, (4) not meeting diagnostic criteria for diabetes at the time of screening, and (5) lack of engagement in any structured weight-loss intervention in the 6 months prior to the study. The current study and the USC CORC studies that contributed data to it were approved by the Health Sciences Institutional Review Board at USC.

Studies recruited different, but overlapping, age groups ranging from 8 to 18 years. All studies used similar recruitment sites located in the urban areas of Los Angeles with a dense population of Hispanic residents and followed similar data collection protocols, permitting data harmonization across studies. All baseline data were collected between 2001 and 2011.

Anthropometry

After an overnight fast, all participants received a medical history exam during an initial outpatient visit at the USC Clinical Trials Unit (CTU). Tanner pubertal stage was established and weight was measured to the nearest 0.01 kg, height to the nearest 1 cm, and waist circumference (WC) to the nearest 1 cm.

Metabolic Measures

An oral glucose tolerance test (OGTT) was conducted at the outpatient visit. Weeks later, participants returned for an overnight stay at the CTU, where dual x-ray absorptiometry scans were used to determine percent body fat (%BF). After an overnight fast at the CTU, an intravenous glucose tolerance test (IVGTT) was administered. Detailed descriptions of the protocols used for the inpatient and overnight CTU visits have been published previously.[42,43]

Where available, data on fasting insulin and fasting glucose from the IVGTT were used to calculate the HOMA score for IR. Where not available, data from the OGTT were used. HOMA was calculated as [fasting glucose (mg/dL) × fasting insulin (μIU/mL)]/405.

Buffer Building

Participants' addresses were geocoded using ArcGIS (Version 10, ESRI, Redlands CA) automated procedures to within 50 m of the nearest street segment and used to create geographic buffers representing the walkable environment, which could theoretically impact youths' residential neighborhood-based food and physical activity behaviors.[18] For 2% of addresses, errors in street spelling were corrected and matched manually to one of two basemaps. All but one address were successfully geocoded. Fifteen subjects located outside of Los Angeles County were excluded, resulting in 611 participants for this analysis.

There is no well-established precedent for identifying optimal walking-distance buffer sizes. In addition, neighborhood environment effect sizes can change by buffer size.[52,53] Therefore, 0.5-, 1-, and 2-mile walking-distance buffers were created to represent a reasonable range of walking distances for adolescents. These walking-distance buffers were generated by traversing all possible routes for a given distance on a street network away from a location.[54,55]

Access to pedestrian paths and U-turns at all intersections were enabled, whereas access to vehicle-only road segments and enforcement of street direction were disabled during buffer calculation. The resulting buffers more accurately captured neighborhood exposure based on actual travel distances than circular buffers with the same fixed radius.[54]

Neighborhood Sociocultural Characteristics

Using data on income, linguistic isolation, and the Hispanic population from the 2000 Census at the Census tract level, neighborhoods were characterized by Hispanic population, median household and median Hispanic household income, and linguistic isolation. Linguistic isolation was measured by the Census as households where no adults speak English "very well."[56] A measure of neighborhood-level acculturation was calculated based on Census data as the proportion of Spanish-speaking households reporting to be "linguistically isolated."

Neighborhood Built Environment

Restaurant locations in Los Angeles County in 2010 were extracted from data provided by InfoUSA. To focus the analysis on major fast-food chain restaurants specifically, locations for six major fast-food franchises used in previous studies on geographic food access in the Los Angeles area[57] were extracted from InfoUSA North

Table 1. Descriptive statistics stratified by gender

	Boys (*n*=211)				Girls (*n*=242)			
Variable	M	SD	Minimum	Maximum	M	SD	Minimum	Maximum
Insulin resistance, homeostasis model assessment score	4.04	2.57	0.51	19.11	4.60	2.65	0.04	21.58
Age, years	12.45	2.55	8	18	12.61	2.84	8	17
Tanner pubertal stage	2.52	1.61	1	5	3.38	1.56	1	5
Waist circumference, cm	91.76	16.28	44.10	147.50	89.23	17.03	52.17	142.50
Body fat, %	35.37	7.34	11.18	52.33	39.84	5.51	16.99	54.16
Fast-food restaurants								
0.5-mile buffer	0.70	0.93	0	4	0.69	0.91	0	3
1-mile buffer	2.59	2.02	0	9	2.68	1.72	0	8
2-mile buffer	10.28	5.40	2	29	10.19	4.94	1	31
Convenience stores								
0.5-mile buffer	1.87	1.90	0	10	1.83	1.71	0	10
1-mile buffer	8.11	6.90	0	41	7.74	6.57	0	46
2-mile buffer	33.68	27.07	7	159	32.30	23.23	1	158
Park space acres	3.74	5.61	0	46.88	4.45	6.58	0	42.34
Park space								
1-mile buffer, acres	23.31	20.28	0	93.92	23.07	19.6	0	120.05
2-mile buffer, acres	118.02	78.21	24.83	454.20	120.04	73.57	24.83	483.64
Junctions/square mile								
0.5-mile buffer	266.02	123.07	84	756	271.08	129.24	75	762
1-mile buffer	257.89	82.86	109	535	263.93	86.52	109	535
2-mile buffer	246.41	58.34	144	356	250.53	56.84	145	362
Hispanic, %	76.48	19.74	2.57	99.42	74.75	21.63	7.42	99.42
Median Hispanic household income, $1000	30.58	9.59	14.64	71.00	29.55	10.96	14.54	135.45
Spanish-speaking households that are linguistically isolated, %	34.17	12.73	2.41	67.60	35.76	11.92	0	66.74

American Industry Classification System (NAICS) code 72211019 by name: (1) McDonald's, (2) Burger King, (3) Wendy's, (4) Kentucky Fried Chicken, (5) Taco Bell, and (6) Pizza Hut.

All convenience store locations were extracted using NAICS code 445120. Convenience stores and fast-food restaurants were counted for each buffer size. Park data from 2007 were provided by the GreenVisions plan for 21st-Century Southern California. Park density was operationalized as aggregate park space in acres for each buffer. A 2010 ESRI street map was used to calculate the number of connections involving at least three street segments per square mile to characterize neighborhood walkability.

Statistical Analysis

Preliminary analysis. All analyses were performed using SAS version 9.2 (SAS Institute, Cary NC). Because of the positive skew of the HOMA score distribution, analyses were performed using a natural log transformation. Bivariate analyses indicated different patterns of association between neighborhood factors and IR between boys and girls, which were evaluated with stratified analyses.

Age, Tanner stage, and WC were correlated with IR. Partialing out the effect of these three factors, Pearson partial correlation coefficients between IR and neighborhood environment variables were estimated at each buffer size. Variables with Pearson partial correlation coefficients significant at the $p<0.10$ level were retained for multivariate regression modeling.

Preliminary model building using multilevel models nested at the Census tract level yielded nonsignificant estimates for the subject-specific random intercepts on IR. Additionally, semivariograms of the data did not reveal patterns consistent with spatial dependence, suggesting little evidence for clustering within Census tracts. Subsequent regression models were built using linear regression models.

Model building. Variables significantly associated with IR in the bivariate analyses were entered into separate multivariate regression models by gender. For variables with correlations at more than one buffer size, the size that produced the best model fit was retained. Because adiposity and visceral adipose tissue are independently related with IR,[58,59] models were adjusted for both %BF and WC.

Models were also adjusted for neighborhood socioeconomic and sociocultural aspects. Taking into account social norms that can affect how youths of differing body size interact with the built environment,[60–63] two-way interactions between WC and each neighborhood environment variable significantly correlated with IR were tested. With the exception of age, which was included in both final models, variables with nonsignificant coefficients were removed to produce the most parsimonious final model.

Results

Participant residences were located most frequently in East and South Los Angeles, which contain both urban and suburban neighborhoods, with predominantly Hispanic populations. Table 1 contains descriptive statistics for the analyzed sample (n=242 girls, 211 boys), and

Table 2. Pearson correlation coefficients between insulin resistance and neighborhood environment variables in boys (n=211)

		1	2	3	4	5	6	7	8	9	10
1	HOMA[a]	1									
2	Fast-food restaurants: 1-mile walking distance	**0.162***	1								
3	Fast-food restaurants: 2-mile walking distance	**0.133***	**0.648****	1							
4	Convenience stores: 0.5-mile walking distance	**0.151***	**0.644****	**0.678****	1						
5	Acres of park space: 0.5-mile walking distance	—[b]	—	—	0.113	1					
6	Acres of park space: 1-mile walking distance	—	—	**0.160***	0.113	**0.467****	1				
7	Acres of park space: 2-mile walking distance	**−0.168***	—	—	**−0.112**	**0.214****	**0.527***	1			
8	Neighborhood Hispanic, %	—	—	—	—	**−0.146***	—	**−0.135***	1		
9	Neighborhood linguistic isolation, %	—	**0.525****	**0.592****	**0.554****	—	—	—	**0.335****	1	
10	Neighborhood median household income, $1000	—	**−0.446****	**−0.401****	**−0.348****	—	−0.129	—	**−0.382****	**−0.770****	1

Note: Boldface indicates significance.
[a]Insulin resistance measured by homeostasis model assessment (HOMA) score
[b]Dashes indicate correlation coefficient $p>0.10$ and are omitted from the table
*$p<0.05$, **$p<0.01$

Table 3. Pearson correlation coefficients between insulin resistance and neighborhood environment variables in girls (n=238)

		1	2	3	4	5	6	7	8	9	10
1	HOMA[a]	1									
2	Fast-food restaurants: 1-mile walking distance	–[b]	1								
3	Fast-food restaurants: 2-mile walking distance	–	**0.535****	1							
4	Convenience stores: 0.5-mile walking distance	–	**0.456****	**0.464****	1						
5	Acres of park space: 0.5-mile walking distance	**−0.153***	–	–	–	1					
6	Acres of park space: 1-mile walking distance	−0.120	–	–	–	**0.537****	1				
7	Acres of park space: 2-mile walking distance	**−0.177****	**0.183****	–	–	**0.231****	**0.533****	1			
8	Neighborhood Hispanic, %	–	–	–	–	–	0.110	–	1		
9	Neighborhood linguistic isolation, %	–	**0.269****	**0.378****	**0.392****	–	**0.157***	0.116	**0.424****	1	
10	Neighborhood median household income, $1000	–	**−0.268****	−0.359	−0.253	–	**−0.188****	**−0.217****	**−0.367****	**−0.719****	1

Note: Boldface indicates significance.
[a]Insulin resistance measured by homeostasis model assessment (HOMA) score
[b]Dashes indicate correlation coefficient $p>0.10$ and are omitted from the table
$^{*}p<0.05$, $^{**}p<0.01$

distributions of neighborhood environment variables in the final regression models.

The mean HOMA score was 4.04 for boys and 4.60 for girls. Ages ranged from 8 to 18 years for boys, and 8 to 17 years for girls; the mean age was approximately 12 years for both sexes. Among boys, the mean WC was 91 cm and the mean %BF was 35%. Among girls, the mean WC was 89 cm and the mean %BF was 39%.

All participants resided in neighborhoods with an average of 4 acres of park space within a 0.5 mile, three fast-food restaurants within 1 mile, and 120 acres of park space within 2 miles. The mean percent Hispanic population was approximately 75%. Hispanic household income was approximately $30,000. The mean neighborhood linguistic isolation was approximately 35%.

Relationship Between Insulin Resistance and Built Environment

Tables 2 and 3 show significant Pearson partial correlation coefficients between IR, individual-level covariates, and neighborhood environment variables stratified by gender. To focus the information presented, only variables included in the final regression models and correlations with $p<0.10$ appear in Tables 2 and 3.

Table 4. Regression coefficients and *p*-values for linear regression models of insulin resistance by gender

	Boys		Girls	
Variable	β (SD)	*p*	β (SD)	*p*
Intercept	**−0.801 (0.282)**	**0.005**	**−2.277 (0.603)**	**<0.0001**
Age, years	0.024 (0.018)	0.198	**−0.036 (0.015)**	**0.020**
Body fat, %	**0.024 (0.006)**	**<0.0001**	—	—
Waist circumference, cm	**0.012 (0.003)**	**<0.0001**	**0.045 (0.007)**	**<0.0001**
Fast-food restaurants (1-mile buffer)	**0.059 (0.003)**	**0.003**	—	—
Park space (0.5-mile buffer), acres	—	—	**−0.013 (0.016)**	**0.012**
Park space (2-mile buffer), acres	**−0.001 (0.019)**	**0.001**	—	—
Spanish-speaking households that are linguistically isolated, %	**−0.006 (0.0004)**	**0.046**	**0.054 (0.005)**	**0.001**
Waist circumference × linguistic isolation	—	—	**−0.001 (0.0002)**	**0.002**
R^2	0.373		0.364	
n	211		242	

Note: Boldface indicates coefficients with $p<0.05$.
[a]Dashes indicate that regression coefficient was omitted from the model for parsimony

Among boys, a negative association was found for acres of park space within 2 miles. IR was positively correlated with fast-food restaurant density within 1 and 2 miles, and with convenience store density within 0.5 mile. Among girls, a negative association was found between acres of park space and IR. This association was significant at all three buffer sizes. No other built environment variables were significantly correlated with IR among girls.

Table 4 compares the final regression models for boys and girls. Multivariate regression models for IR among boys indicated that age was not significantly associated, but increasing %BF and WC were both independently associated with IR. Fast-food restaurants and park space remained significantly associated with IR, but convenience store density was no longer significant.

Among boys, the best-fit model included fast-food restaurants within 1 mile and acres of park space within 2 miles. The combined effect of fast food, park space, and neighborhood linguistic isolation explained 6% of the variance in HOMA scores. The remaining 31% of the variance was explained by %BF and WC.

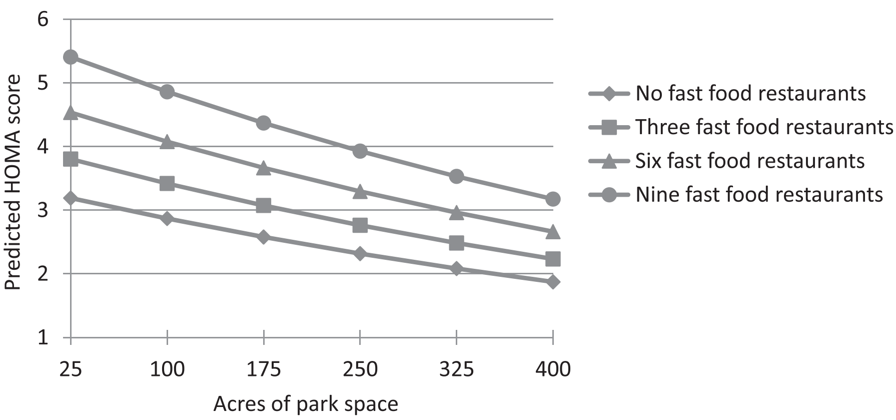

Figure 1. Predicted homeostasis model assessment (HOMA) scores among boys by fast-food access and acres of park space
Note: Acres of park space are within a 2-mile walking-distance buffer; fast-food restaurants are within a 1-mile walking-distance buffer. Values in this figure are based on average sample characteristics: boys, aged 12 years, with a 90-cm waist circumference, 35% body fat, and 35% neighborhood linguistic isolation.

Among boys, these results can be interpreted on the linear scale as a 6% ($e^{0.059}$=1.06) greater HOMA score for each additional major chain fast-food restaurant within a 1-mile walking-distance buffer. Each additional acre of park space was associated with a 0.1% lower HOMA score. Each additional percent of linguistically isolated Spanish-speaking households was associated with a 0.6% lower HOMA score.

Figure 1 illustrates the relationship between fast-food restaurant density and HOMA score, on a linear scale, across increasing acres of park space among boys with the following average sample characteristics: aged 12 years, 90 cm WC, 35% body fat, and 35% neighborhood linguistic isolation. In this illustration, a boy with 175 acres of park space within 2 miles and no fast-food restaurants within 1 mile would have a HOMA score of 2.57, or 1.79 points less than a HOMA score of 4.36 predicted for a similar boy with nine fast-food restaurants within 1 mile.

Also illustrated in Figure 1, boys who live in neighborhoods with six fast-food restaurants within 1 mile and 25 acres of park space within 2 miles have a predicted HOMA score of 4.53, or 1.24 points lower than the predicted HOMA score of 3.29 among boys that have 250 acres of park space within 2 miles.

Among girls, more acres of park space using a 0.5-mile walking-distance buffer was associated with lower IR, but greater neighborhood linguistic isolation was associated with higher IR in the multivariate regression models. Furthermore, the significant interaction between WC and neighborhood linguistic isolation indicates that greater linguistic isolation is associated with higher predicted HOMA score, but only among girls with lower WCs.

The opposite effect was found for girls with higher WCs. The multivariate regression model that produced the best fit yielded an R^2 value of 0.364. The combined effects of park space, neighborhood linguistic isolation, and its interaction term with WC accounted for 5% of the variance in HOMA scores, whereas age and WC explained 31% of this variation.

Figure 2 illustrates the effect modification by WC on HOMA scores among girls on a linear scale. Estimates for boys' predicted HOMA scores based on the final regression model using average sample characteristics are also illustrated. Greater neighborhood linguistic isolation was associated with lower HOMA scores for girls with larger WCs and higher HOMA scores for those with smaller WCs.

Figure 3 shows the relationship between the amount of park space and HOMA score, across quartiles of neighborhood linguistic isolation, among girls with the average sample characteristics (aged 12 years and 90 cm WC). Girls living in neighborhoods with 30% linguistic isolation and 10 acres of park space within 0.5 mile have a predicted HOMA score of 3.62, or 1.48 points higher than similar girls with 50 acres of park space within 0.5 mile with a predicted HOMA score of 2.14.

Discussion

In this population, a relationship exists between aspects of the built environment and IR, even after controlling for %BF and WC. Although this study is cross-sectional, it provides novel insight into the influence of food environment and public park space in a high-risk population. Overweight and obese youth are at higher risk of developing IR and type 2 diabetes compared to normal-weight youth. Furthermore, Hispanic youth are at higher risk of metabolic abnormalities than others, especially when they are overweight or obese.[30,64]

Reducing neighborhood density of fast-food restaurants and increasing public park space may be valuable approaches to preventing type 2 diabetes. Although associations with fast-food restaurants may be attenuated owing to the focus on only six major franchise restaurants, these findings are more generalizable, as all are located in cities across the U.S.

Importantly, this study indicates that relationships between the built environment and IR differ by gender. These differences might be explained by differing pathways to independent mobility between girls and boys, with boys more likely to gain independent mobility and more freedom to travel than girls.[63] Boys may be using this freedom to travel outside the home and have more opportunities to visit fast-food restaurants. Lack of such freedom for girls may also explain why the locus of park effects occurs at a smaller distance. These differences suggest the necessity of studying the impact of the built environment separately for boys and girls.

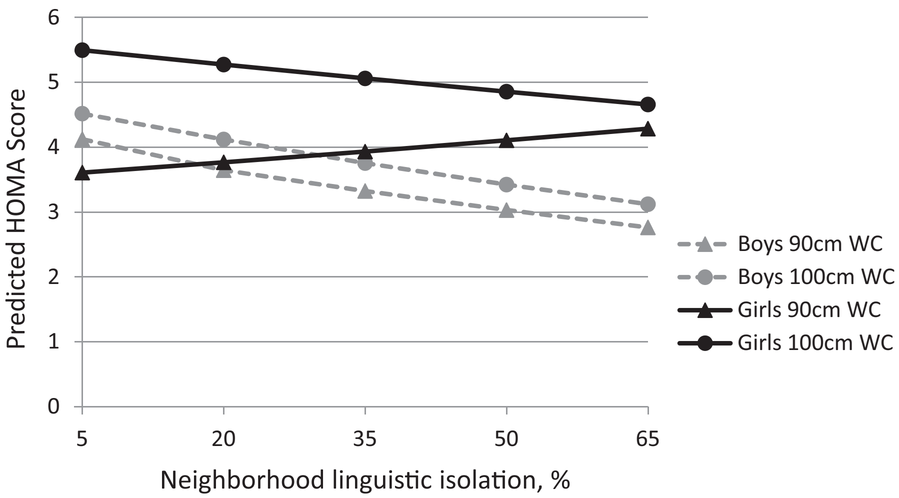

Figure 2. Predicted homeostasis model assessment (HOMA) scores by gender, neighborhood linguistic isolation, and waist circumference

Note: HOMA scores are based on average sample characteristics: boys, aged 12 years, 35% body fat, three fast-food restaurants within a 2-mile walking-distance buffer, and 120 acres of park space within a 1-mile walking-distance buffer, or girls, aged 12 years, 5 acres of park space within a 1-mile walking-distance buffer.

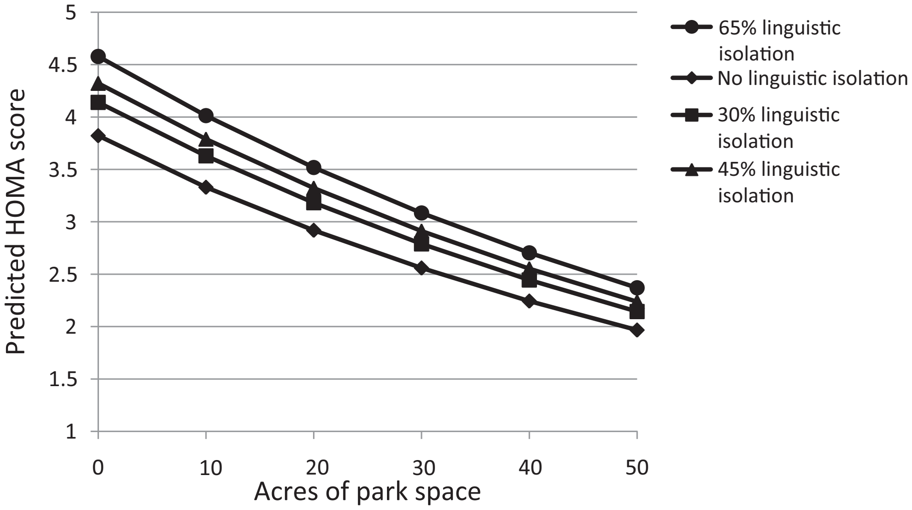

Figure 3. Predicted homeostasis model assessment (HOMA) scores among girls by linguistic isolation and acres of park space

Note: Acres of park space are within a 0.5-mile walking distance buffer. HOMA scores in this figure are based on average sample values: girls, aged 12 years, with a 90-cm waist circumference.

For both genders, built environment and neighborhood sociocultural aspects explained approximately 5%–6% of the variance in HOMA scores. Although this is a relatively small portion compared to the 30%–31% of variance explained by age, %BF, and WC, it is a substantial contribution for neighborhood effects, which are often diffuse. Even with these small effects, the neighborhood environment may profoundly affect population rates of IR and related overall health burden.

Furthermore, although the cross-sectional nature of this analysis precludes attributing causal relationships, the evidence presented warrants further investigation. "Natural experiments"—such as when neighborhood characteristics are changed through governmental interventions on the built environment or school policies—could offer opportunities to investigate whether the relationships identified in this study are likely causal.

Notably, the risk contributed by the neighborhood environment may exceed what the current findings suggest, as park access, fast-food access, and neighborhood sociocultural factors have been linked to obesity. Because this study adjusted for body fat and abdominal adiposity, it illustrates the risk associated with IR independent of adiposity. The neighborhood environment's impact on both obesity and IR may amplify the effects of risky environments. Additionally, as all contributing studies screened for diabetes, exclusion of participants with the highest IR levels may have attenuated the present findings.

Conclusions

This study has provided novel insight into the potential influence of access to healthier food choices and public park space in a high-risk population. The findings affirm the need to further investigate relationships between the built environment and IR, and demonstrate the need to account for gender differences in these relationships.

Although the obesity literature indicates that the impact of the food and physical activity environment on obesity differs by gender, the findings are varied.[20,65,66] No other studies to date have investigated effect modification of the association between the built environment and IR or diabetes by gender.

Future research may establish how aspects of the neighborhood environment relate to IR and further investigate differences between boys and girls. These efforts will enhance our understanding of the health effects of the neighborhood built environment and inform more-effective intervention and policy efforts to reduce the risk of obesity and diabetes among at-risk populations.

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