Effect of Individual or Neighborhood Disadvantage on the Association Between Neighborhood Walkability and Body Mass Index

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Objectives. We sought to test whether the association between walkable environments and lower body mass index (BMI) was stronger within disadvantaged groups that may be particularly sensitive to environmental constraints.

Methods. We measured height and weight in a diverse sample of 13 102 adults living throughout New York City from 2000–2002. Each participant's home address was geocoded and surrounded by a circular buffer with a 1-km radius. The composition and built environment characteristics of these areas were used to predict BMI through the use of generalized estimating equations. Indicators of individual or area disadvantage included low educational attainment, low household income, Black race, and Hispanic ethnicity.

Results. Higher population density, more mixed land use, and greater transit access were most consistently associated with a lower BMI among those with more education or higher incomes and among non-Hispanic Whites. Significant interactions were observed for education, income, race, and ethnicity.

Conclusions. Contrary to expectations, built environment characteristics were less consistently associated with BMI among disadvantaged groups. This pattern may be explained by other barriers to maintaining a healthy weight encountered by disadvantaged groups. (*Am J Public Health.* 2009;99:279–284. doi:10.2105/AJPH.2008.138230)

Urban environments have recently been studied for their effects on diet, physical activity, obesity, and obesity-related health conditions.[1–4] Metropolitan areas and counties characterized as compact, rather than sprawling, may facilitate walking for transportation and may curb obesity.[5,6] Yet, metropolitan areas are far from homogeneous, and neighborhood-level measures of the built environment have also been associated with obesity.[1] Within New York City, for example, higher population density, more mixed land uses, and access to public transit near the home were associated with lower body mass index (BMI).[7]

Neighborhood socioeconomic disadvantage and racial or ethnic composition have also been examined as predictors of obesity[8] and as potential confounders in studies of other environmental features. Research on the built environment and obesity has recently begun to consider whether population characteristics might modify the effect of built environment characteristics on obesity and related behaviors.[9–11] Speculation as to which populations would be most sensitive to the obesity-related effects of the built environment has yielded competing hypotheses. Several authors have posited that poor or disadvantaged groups would be most likely to respond to their residential environment, lacking means to go elsewhere.[1,8] On the other hand, some disadvantaged individuals may be "captive walkers" who rely on walking for transportation,[12] thus being unable to respond to the local environment by retreating into their vehicles. Meanwhile, the often discussed problem of "self-selection" could bias observational studies of neighborhoods and health[13] and could imply that relatively affluent and advantaged individuals will have the strongest (albeit noncausal) associations between their neighborhood environment and obesity because more resources facilitate the selection of an environment to fit one's preferred lifestyle. Finally, measurement error or unmeasured environmental characteristics may differ depending on the characteristics of the population studied. Ostensibly "walkable" neighborhoods may be less safe or attractive in more deprived areas.[14–17] Also, the use of paid gyms and the norms related to food or activity may differ by population,[18] and the culturally mediated response to environmental features may differ as well.[19,20]

We report stratified analyses from a large, diverse population in New York City to shed light on these ideas. We a priori identified 4 population characteristics that identify disadvantaged individuals and neighborhoods: low educational attainment, low household income, Black race, and Hispanic ethnicity. Competing hypotheses from the published literature predict stronger or weaker associations for disadvantaged populations.

METHODS

Setting and Population

Our analyses used data collected during the baseline enrollment of participants for the New York Cancer Project. Between January 2000 and December 2002, research staff carried out extensive publicity and recruitment efforts throughout New York City and surrounding suburbs to recruit an ethnically and socioeconomically diverse convenience sample of 18 187 volunteers. Data collection took place at 6 community-based health centers, 2 community hospitals, 6 medical centers and the New York Blood Center. Qualifications for enrollment included a minimum age of 30 years and a literacy level high enough to complete a follow-up questionnaire.

Of the total sample, 14 147 individuals had geocoded addresses falling within New York City boundaries, and 13 102 had a BMI of less than 70 kg/m^2 (weight in kilograms divided by height in meters squared) and complete data for objectively measured height and weight and questionnaire measures of key covariates (age, race/ethnicity, gender, income, and educational attainment). The demographic profile and spatial distribution of the sample were similar to those derived from the 2000 Census[21] and from the 2002 New York Community

TABLE 1—Variation in Body Mass Index (BMI) and the Built Environment, by Education, Income, Race, and Ethnicity: New York City, 2000–2002

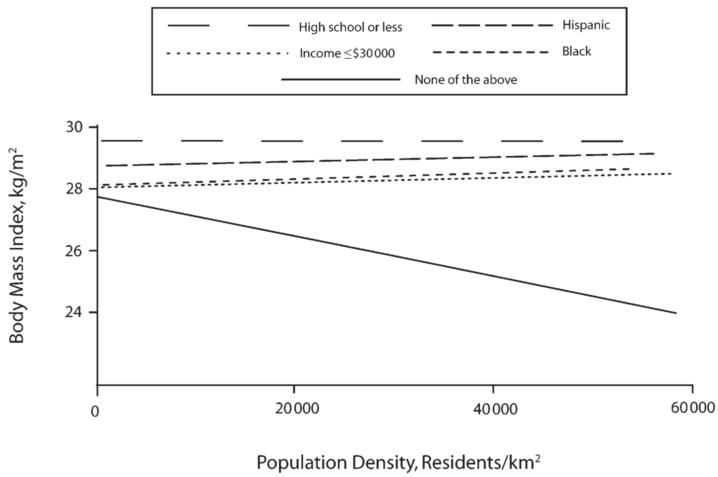
	No.	BMI, kg/m^2, Mean	Population Density, 10 000/km^2, Median (25th, 75th Percentiles)	Land Use Mix,[a] Median (25th, 75th Percentiles)	Public Transit Use, %, Median (25th, 75th Percentiles)	Subway Access, stops/km^2, Median (25th, 75th Percentiles)	Bus Access, Stops/km^2, Median (25th, 75th Percentiles)
Overall	13 102	27.8	1.57 (0.74, 2.48)	0.36 (0.26, 0.55)	0.52 (0.39, 0.62)	0.89 (0.00, 1.59)	17.67 (12.81, 23.56)
Individual							
Less than a high school education	4560	28.3	1.67 (0.82, 2.55)	0.38 (0.27, 0.55)	0.53 (0.42, 0.63)	0.96 (0.00, 1.61)	18.15 (13.37, 23.88)
Income ≤$30 000	3446	28.2	2.08 (1.40, 2.92)	0.40 (0.29, 0.57)	0.57 (0.49, 0.65)	1.27 (0.64, 1.91)	20.37 (15.60, 25.85)
Black race	2478	29.6	1.80 (1.05, 2.55)	0.36 (0.26, 0.53)	0.60 (0.47, 0.67)	0.96 (0.00, 1.66)	19.95 (15.05, 25.15)
Hispanic ethnicity	2633	28.9	1.94 (1.21, 2.93)	0.40 (0.28, 0.55)	0.58 (0.49, 0.64)	1.11 (0.49, 1.83)	19.55 (14.82, 24.83)
None of the above	5037	26.7	1.33 (0.55, 2.21)	0.34 (0.25, 0.55)	0.48 (0.29, 0.58)	0.64 (0.00, 1.47)	16.55 (11.78, 22.87)
Neighborhood							
Low education	3273	28.5	2.51 (1.86, 3.20)	0.44 (0.33, 0.58)	0.61 (0.53, 0.66)	1.59 (1.05, 1.96)	22.92 (18.46, 27.42)
Low income	3276	28.7	2.53 (1.93, 3.16)	0.43 (0.31, 0.57)	0.62 (0.54, 0.66)	1.59 (0.99, 1.98)	23.24 (18.46, 27.69)
Predominately Black	3275	29.3	1.80 (1.06, 2.59)	0.37 (0.26, 0.53)	0.62 (0.48, 0.67)	0.96 (0.00, 1.69)	19.74 (14.96, 25.23)
Predominately Hispanic	3276	28.5	2.36 (1.65, 3.10)	0.42 (0.31, 0.55)	0.61 (0.56, 0.66)	1.29 (0.96, 1.91)	21.33 (16.92, 25.48)
None of the above	7003	27.1	1.10 (0.52, 1.84)	0.33 (0.24, 0.52)	0.44 (0.28, 0.56)	0.34 (0.00, 1.13)	15.60 (11.15, 21.13)

Note. The mean BMI (weight in kilograms divided by height in meters squared) was significantly higher for each disadvantaged group (*t* test, $P < .001$).
[a]Range: 0–1.

Health Survey, a random-digit-dialed health survey of New Yorkers conducted by the New York City Department of Health.[7] At the time of enrollment, written informed consent was obtained in person by research staff.

Built Environment Measures

Each participant's home address was geocoded and surrounded by a circular buffer with a radius of 1 km. These 1-km buffers were characterized with respect to population density, land use mix, transit use, and transit stops. The measure of population density was constructed from the 2000 Census[21] and was expressed as persons per square kilometer of land area (excluding water). The measure of land use mix was constructed by using a parcel-level dataset, the Primary Land Use Tax Lot Output data, available from the Department of City Planning (http://www.nyc.gov/html/dcp/html/bytes/applbyte.shtml). The numbers of bus and subway stops per square kilometer were calculated from data provided by the New York City Metropolitan Transportation Authority (http://www.mta.info).



Note. This figure was created on the basis of a model adjusted for age, gender, individual race/ethnicity, individual education, and the percentage of area residents who were Black, the percentage who were Latino, and the percentage below the federal poverty line; differences in the starting and ending values for the lines shown reflect subgroup differences in the range of observed environment characteristics. Body mass index was calculated as weight in kilograms divided by height in meters squared.

FIGURE 1—Adjusted association between population density and body mass index: New York City, 2000–2002.

Socioeconomic and Demographic Measures

Demographic and socioeconomic characteristics were used to identify disadvantaged individuals and areas. We dichotomized education, income, race, and ethnicity to present stratified results based on self-reported data at the individual level or US Census data for the year 2000, summary file 3.[21]

At the individual level, education disadvantage was defined as high school graduation or less, income disadvantage as a household income of $30 000 per year or less, Black race as non-Hispanic African American or non-Hispanic Caribbean, and Hispanic ethnicity as

TABLE 2—Association Between Built Environment Characteristics and Body Mass Index, by Individual Education, Income, Race, and Ethnicity: New York City, 2000–2002

Neighborhood Characteristic	Disadvantaged Group, Parameter Estimate (95% CI)	Advantaged Group, Parameter Estimate (95% CI)	*P* for Interaction
High school or less versus more than high school			
Population density	0.10 (−0.16, 0.36)	−0.54 (−0.63, −0.45)	.002
Land use mix	−0.11 (−0.96, 0.73)	−1.42 (−2.07, −0.78)	.041
Public transit use	0.28 (−1.62, 2.19)	−4.96 (−6.15, −3.78)	.190
Subway access	−0.12 (−0.27, 0.04)	−0.36 (−0.48, −0.24)	.057
Bus access	0.02 (−0.01, 0.05)	−0.07 (−0.08, −0.05)	.001
$30 000 or less versus more than $30 000			
Population density	0.08 (−0.17, 0.33)	−0.56 (−0.68, −0.43)	<.001
Land use mix	−1.16 (−1.92, −0.41)	−1.17 (−1.89, −0.45)	.894
Public transit use	−0.56 (−2.70, 1.59)	−4.86 (−6.06, −3.66)	.528
Subway access	−0.13 (−0.24, −0.01)	−0.38 (−0.52, −0.24)	.064
Bus access	−0.00 (−0.03, 0.02)	−0.06 (−0.08, −0.04)	.026
Black versus other			
Population density	0.00 (−0.26, 0.27)	−0.46 (−0.58, −0.35)	.032
Land use mix	−0.47 (−1.65, 0.71)	−1.15 (−1.76, −0.55)	.197
Public transit use	−1.44 (−4.08, 1.20)	−4.15 (−5.43, −2.86)	.331
Subway access	−0.15 (−0.42, 0.12)	−0.32 (−0.43, −0.21)	.232
Bus access	0.00 (−0.03, 0.04)	−0.05 (−0.07, −0.03)	.033
Hispanic versus other			
Population density	0.07 (−0.20, 0.34)	−0.51 (−0.62, −0.40)	.005
Land use mix	−0.52 (−1.61, 0.57)	−1.18 (−1.79, −0.57)	.426
Public transit use	−0.01 (−2.72, 2.71)	−4.47 (−5.73, −3.21)	.013
Subway access	−0.02 (−0.27, 0.22)	−0.35 (−0.45, −0.24)	.043
Bus access	0.00 (−0.03, 0.04)	−0.05 (−0.07, −0.03)	.021
None of the above			
Population density	. . .	−0.65 (−0.78, −0.52)	<.001
Land use mix	. . .	−1.69 (−2.54, −0.84)	.011
Public transit use	. . .	−5.80 (−7.10, −4.51)	<.001
Subway access	. . .	−0.44 (−0.60, −0.28)	.004
Bus access	. . .	−0.08 (−0.11, −0.06)	<.001

Note. CI = confidence interval. All models were adjusted for age, gender, individual race/ethnicity, individual education, and the percentage of area residents who were Black, the percentage who were Hispanic, and the percentage below the 2000 federal poverty line.[21]

Hispanic or Latino. For area-level disadvantage, we identified the quartile of study participants living in areas with the lowest proportion of high school graduates (based on residents over the age of 25 years), the quartile with the highest proportion of individuals below the federal poverty line, the quartile with the highest percentage of Black residents, and the quartile with the highest percentage of Hispanic residents. At the individual and area levels, we also identified a stratum of participants not meeting any of the above criteria for disadvantage. The cutoffs used to dichotomize these variables were selected after we examined the distribution of each variable but before we examined stratified regression models.

Statistical Analysis

Descriptive statistics were used to summarize the variation in built environment characteristics for the entire study population and for population subgroups. Mean BMI values for the population subgroups are also shown. We used the *t* test without an equal variance assumption to assess whether each subgroup differed significantly from the rest of the study population.

Generalized estimating equation models were created within strata based on individual or area education, income, race, and ethnicity. BMI was treated as a continuous outcome, and robust standard errors were used to account for clustering within United Hospital Fund areas (health reporting districts in New York City). All models included individual and area characteristics that were viewed as potential confounders: age, gender, race/ethnicity, and educational attainment of the individual and the percentage of area residents who were Black, the percentage who were Latino, and the percentage who were below the federal poverty line. Built environment characteristics were each modeled separately. Interaction *P* values were calculated based on models of the entire study population; likelihood ratio tests were used to assess the significance of an interaction term for the disadvantage indicator and built environment characteristic.

RESULTS

Our study population included 13 102 adults, with a mean age of 46 years and a mean BMI of 28 kg/m^2, of whom 65% were women. The built environment characteristics near the participants' homes varied substantially, even within disadvantaged subgroups (Table 1).

The associations between built environment characteristics and BMI were strongest and most consistent for non-Hispanic Whites and those with relatively more education or income (Table 2, Figure 1). All estimates were significant and in the expected direction for those within the more advantaged strata. For several built environment characteristics, we detected significant interactions with one or more indicators of disadvantage.

The associations between built environment characteristics and BMI were also most consistent within advantaged areas (Table 3; see figures available as a supplement to the online version of this article at http://www.ajph.org). Once again, all estimates of those within more advantaged strata were significant and in the expected direction, and several interactions were statistically significant.

Our results were based on a 1-km radial buffer, but a planned sensitivity analysis found similar patterns when using buffers with radii of either 0.5 or 1.5 km. Gender-stratified

TABLE 3—Association Between Built Environment Characteristics and Body Mass Index, by Area-Based Education, Income, Race, and Ethnicity: New York City, 2000–2002

Neighborhood Characteristic	Disadvantaged Area, Parameter Estimate (95% CI)	Advantaged Area, Parameter Estimate (95% CI)	*P* for Interaction
Neighborhood education: low quartile versus others			
Population density	−0.03 (−0.33, 0.28)	−0.50 (−0.61, −0.39)	.022
Land use mix	−0.57 (−1.57, 0.44)	−1.26 (−1.84, −0.69)	.242
Public transit use	−1.28 (−5.45, 2.89)	−4.50 (−5.76, −3.24)	.942
Subway access	−0.12 (−0.29, 0.04)	−0.37 (−0.48, −0.26)	.018
Bus access	0.01 (−0.03, 0.04)	−0.06 (−0.08, −0.04)	.007
Neighborhood poverty: high quartile versus others			
Population density	0.18 (−0.10, 0.45)	−0.53 (−0.63, −0.42)	<.001
Land use mix	−0.68 (−1.68, 0.32)	−1.17 (−1.83, −0.51)	.549
Public transit use	1.63 (−0.74, 3.99)	−4.75 (−5.86, −3.64)	.028
Subway access	−0.08 (−0.27, 0.12)	−0.35 (−0.48, −0.22)	.035
Bus access	0.01 (−0.03, 0.05)	−0.06 (−0.08, −0.04)	.009
Neighborhood race: predominantly Black versus others			
Population density	−0.04 (−0.43, 0.35)	−0.47 (−0.57, −0.37)	.036
Land use mix	−0.11 (−1.20, 0.98)	−1.24 (−1.78, −0.70)	.053
Public transit use	−1.59 (−5.58, 2.41)	−4.21 (−5.39, −3.02)	.130
Subway access	−0.11 (−0.35, 0.13)	−0.33 (−0.44, −0.21)	.134
Bus access	−0.01 (−0.06, 0.04)	−0.05 (−0.07, −0.03)	.158
Neighborhood ethnicity: predominantly Hispanic versus others			
Population density	−0.02 (−0.35, 0.32)	−0.48 (−0.58, −0.38)	.045
Land use mix	−0.19 (−1.15, 0.76)	−1.37 (−1.90, −0.85)	.110
Public transit use	−2.10 (−5.57, 1.36)	−4.21 (−5.50, −2.92)	.567
Subway access	−0.35 (−0.67, −0.03)	−0.30 (−0.40, −0.20)	.603
Bus access	−0.00 (−0.05, 0.04)	−0.06 (−0.08, −0.04)	.068
None of the above			
Population density	...	−0.55 (−0.64, −0.46)	.001
Land use mix	...	−1.58 (−2.13, −1.02)	.018
Public transit use	...	−5.00 (−5.97, −4.02)	.063
Subway access	...	−0.40 (−0.52, −0.29)	<.001
Bus access	...	−0.07 (−0.09, −0.05)	<.001

Note. CI = confidence interval. All models were adjusted for age, gender, individual race/ethnicity, individual education, and the percentage of area residents who were Black, the percentage who were Hispanic, and the percentage who were below the 2000 federal poverty line.[21]

models were examined; once again, for the advantaged groups, all walkability indicators were significantly associated with BMI in the expected direction.

DISCUSSION

We found that the associations between selected built environment characteristics and BMI were strongest and most consistent for relatively advantaged individuals or areas. In fact, we found little evidence that these walkability-related characteristics were associated with BMI for disadvantaged populations or areas.

Absent or unexpected associations between the built environment and obesity have been noted previously for some populations or population subgroups.[1,22–27] A study of diverse women considered predictors of physical activity within racial or ethnic subgroups and did not find consistent effects of the physical environment.[28] For example, a study within a Hispanic population did not find the expected association between land use mix and BMI.[25] Two Atlanta-based studies presented associations stratified by race and found less consistent effects of compact or walkable environments among non-Whites.[9,10] Together with these studies, our findings cast doubt on the relevance of density, land use mix, and transit access as determinants of obesity within disadvantaged groups.

Although there seems to be little empirical support for the hypothesis that disadvantaged populations are particularly sensitive to obesigenic effects of the built environment, the observed pattern could be compatible with several other explanations. The built environment may not be sufficient to promote activity within disadvantaged subgroups because of overriding safety concerns,[29–32] aesthetic problems,[15,17,33–35] or social influences.[18,36] The food environment may also be an important determinant of energy balance, potentially outweighing the importance of walkability.[37–40] As such, the higher obesity prevalence that has been noted for disadvantaged groups in the United States[41] may be "overdetermined" by the simultaneous presence of multiple problems in the environment, one or two of which would be sufficient to discourage healthier behavior patterns. This would suggest that multiple barriers need to be addressed before the benefits of living in a walkable neighborhood can be detected. Alternatively, a supportive built environment may not be necessary to promote walking if disadvantaged populations are captive walkers, constrained to rely on walking for transportation.

Self-selection into residential areas according to preferences could also serve as an explanation for the observed pattern of effect modification. Preferences to be active or avoid weight gain may influence some active and normal-weight individuals to select more compact and walkable neighborhoods.[42] If so, individuals with more resources may be better able to select a residential area that suits their preferences. As a result, the noncausal association between neighborhood characteristics and weight could be stronger among relatively advantaged population subgroups.

Strengths and Limitations

The large, diverse study population used in this analysis afforded us the statistical power necessary to meaningfully evaluate stratified results and interactions. The environmental characteristics and anthropometric data we used were objectively assessed, thus avoiding biases inherent in self-reported data on environments or body weight.

Our study is limited by the cross-sectional and observational study design. Additional limitations include the absence of diet or physical activity measures. Also, we considered only a subset of potentially relevant built environment characteristics, which we selected because of their use in previous studies of walkability.[43–45] Finally, the study population consisted of adult residents of New York City, and the results may not be generalizable to other settings.

Conclusions

In this diverse sample of New York City residents, built environment characteristics related to walkability were associated with BMI, but the association was not uniform across population subgroups. We observed interactions between built environment characteristics and indicators of disadvantage. The strongest and most consistent associations were within advantaged subgroups, as defined by education, income, race, or ethnicity. This pattern may be explained by disadvantaged groups encountering other barriers to maintaining a healthy weight or self-selection being stronger among those with more control over selecting their area of residence. Future research should be designed to distinguish between these explanations, because their implications for health promotion would be quite different. ■

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Contributors

All authors contributed to the study design, analytic approach, and presentation of results. J.W. Quinn constructed neighborhood measures. G.S. Lovasi conducted the statistical analyses and prepared the article with assistance from K.M. Neckerman and C.C. Weiss. All authors critically reviewed drafts and approved the final article.

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Human Participant Protection

Analyses of body mass index, individual demographic variables, and appended neighborhood characteristics were approved by the Columbia University Medical Center institutional review board. At the time of enrollment, written informed consent was obtained in person by research staff.

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