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The Geography of Recreational Open Space: Influence of Neighborhood Racial Composition and Neighborhood Poverty

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ABSTRACT *The geography of recreational open space might be inequitable in terms of minority neighborhood racial/ethnic composition and neighborhood poverty, perhaps due in part to residential segregation. This study evaluated the association between minority neighborhood racial/ethnic composition, neighborhood poverty, and recreational open space in Boston, Massachusetts (US). Across Boston census tracts, we computed percent non-Hispanic Black, percent Hispanic, and percent families in poverty as well as recreational open space density. We evaluated spatial autocorrelation in study variables and in the ordinary least squares (OLS) regression residuals via the Global Moran's I. We then computed Spearman correlations between the census tract socio-demographic characteristics and recreational open space density, including correlations adjusted for spatial autocorrelation. After this, we computed OLS regressions or spatial regressions as appropriate. Significant positive spatial autocorrelation was found for neighborhood socio-demographic characteristics (all p value=0.001). We found marginally significant positive spatial autocorrelation in recreational open space (Global Moran's I=0.082; p value=0.053). However, we found no spatial autocorrelation in the OLS regression residuals, which indicated that spatial models were not appropriate. There was a negative correlation between census tract percent non-Hispanic Black and recreational open space density (r_S=−0.22; conventional p value=0.005; spatially adjusted p value=0.019) as well as a negative correlation between predominantly non-Hispanic Black census tracts (>60 % non-Hispanic Black in a census tract) and recreational open space density (r_S=−0.23; conventional p value=0.003; spatially adjusted p value=0.007). In bivariate and multivariate OLS models, percent non-Hispanic Black in a census tract and predominantly Black census tracts were associated with decreased density of recreational open space (p value<0.001). Consistent with several previous studies in other geographic locales, we found that Black neighborhoods in Boston were less likely to have recreational open spaces, indicating the need for policy interventions promoting equitable access. Such interventions may contribute to reductions and disparities in obesity.*

KEYWORDS *Recreational open space, Neighborhood racial composition, Neighborhood poverty, Racial/socioeconomic segregation, Spatial demography, Boston, US*

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INTRODUCTION

Obesity is an important public health problem, with longstanding disparities.[1,2] A study published in the 1950s, which was representative of the US population, found that Blacks had a higher prevalence of overweight as compared with Whites.[2] These patterns persist today.[1] Determinants of this variation remain elusive, despite considerable work focused on individual-level explanations. There is a need for empirical investigations understanding macro-level influences of socio-demographic disparities in obesity-related outcomes, including studies of the residential and physical environment.

Racial and socio-economic residential segregation, common in the U.S. and some other parts of the world[3], are considered to be a fundamental cause of racial/ethnic health disparities.[4] Research shows that the level of physical activity is lower in racially segregated neighborhoods,[5,6] and several studies have linked residential segregation to obesity.[7–11] Residential segregation is posited to influence obesity disparities and health disparities in general in part by shaping disparities in neighborhood environments.[4,12,13] Research generally has found that disadvantaged groups are more likely to live in neighborhoods with more obesogenic characteristics, including fewer places to be physically active, such as outdoor recreational facilities.[14] However, research in this area overall has been equivocal, with some studies finding no neighborhood socio-demographic disparities (e.g., by minority neighborhood racial/ethnic composition and neighborhood poverty) in recreational access[15–19] and others showing "reverse" disparities, i.e., some studies suggesting that disadvantaged groups have increased access to facilities that promote physical activity.[15,19–25] The heterogeneous findings across the literature may be attributable to the differences in the measures of recreational access, but it is also possible that the association between neighborhood socio-demographic characteristics and facilities that promote physical activity might be context-specific. One study[18] found that percent neighborhood Black was significantly inversely associated with recreational facilities in Baltimore, MD, but found no significant effect in Winston-Salem, NC.

It is important to note that most studies examining disparities in recreational access do not consider potential threshold effects of neighborhood socio-demographic composition. Most studies categorize neighborhood racial/ethnic composition (such as percent Black) as a continuous variable, for example. The level of a dominant racial/ethnic group in a neighborhood could matter in the relationship between neighborhood racial/ethnic composition and the location of facilities that promote physical activity. High levels of minority neighborhood racial/ethnic composition (say 60 % minority) may influence placement of physical activity facilities. Thresholds may influence the spatial distribution of neighborhood amenities, including recreational access, for political, economic, and social reasons. For example, the reputation of an area may influence the decisions of service planners and investors to locate certain goods, services, and amenities in a particular area. Importantly, most studies in this area also do not consider spatial dependence, which is dependence among observations as related to geographic proximity. Spatial dependence of observations is a violation of standard statistical methods and as such should be examined and accounted for if present because findings can change in meaningful ways when spatial autocorrelation is present but not accounted for statistically.[26–30]

In this study, we examined the influence of minority neighborhood racial/ethnic composition and neighborhood poverty as both continuous and categorical variables on recreational open space in Boston, Massachusetts (US), a city that has consistently ranked as one of the top metropolitan areas showing a high degree of residential segregation over the past three decades.[31,32] We used 2010 US Census data and 2006–2010 American Community Survey data for information on neighborhood socio-demographic characteristics. In this research, we specifically focus on recreational open space (downloaded from the Commonwealth of Massachusetts' Office of Geographic Information) because these open spaces provide a platform for recreation especially in urban environments. For instance, people may use open spaces for active recreation including play organized or informal sports and/or to walk or jog, which can promote physical activity and lower obesity.[33]

METHODS

Geographic Region

Boston, Massachusetts (US) is the geographic area under analysis, one of the oldest cities in the US and the largest city in Massachusetts. The spatial coverage of Boston includes a total area of 89.63 square miles, which is 232.14 km^2. Boston has a population of 617,594, according to the 2010 US Census. The census tract was our definition of a neighborhood.[34–38] Census tracts have approximately 4,000 people and are designated as homogenous spatial units "with respect to population characteristics, economic status, and living conditions."[39] In this study, we used 2010 census tract boundaries.

The analytic sample of census tracts included contiguous 2010 census tracts in Boston (n=179) since contiguity matters in spatial analysis of areal data. Specially, we excluded the Harbor Islands, consistent with past neighborhood research in Boston,[38,40,41] and we excluded a census tract that includes only the Massachusetts Bay. The Harbor Islands includes a small population of 535 individuals who are not typical of the rest of the city, e.g., there is a detoxification center there with permanent residents. Additionally, consistent with previous socio-demographic disparities research,[38,42] our analysis was further restricted to those census tracts with >500 people (n=167). Census tracts with fewer than 500 people were dropped specifically because the American Community Survey generally does not release data for populations <500 at this scale for reasons of preserving anonymity. Because extremely small populations in census tracts can bias the results, removing these sparsely populated census tracts also ensures that census tracts with extremely small populations would not bias the results.

Neighborhood Racial Composition

Minority neighborhood racial/ethnic composition is a marker of racial residential segregation. Using 2010 US Census data, we measured percent of non-Hispanic Black residents and percent of Hispanic residents as indicators of minority neighborhood racial/ethnic composition, which were downloaded from Social Explorer. These were measured as continuous variables and categorical variables. Similar to past research [21,43,44], neighborhoods with >60 % Black and Hispanic populations were considered as predominantly Black and Hispanic neighborhoods, respectively.

Neighborhood Poverty

Data for the percent of families 100 % below the federal poverty level came from the 2006–2010 American Community Survey because data on neighborhood-level socioeconomic conditions were not obtained in the 2010 US Census. American Community Survey data on census tract neighborhood poverty were downloaded from Social Explorer. Neighborhood poverty both was operationalized as a continuous variable and categorical variable. High poverty neighborhoods were defined as at least 20 % of families in poverty in an area, which is consistent with previous research.[25,35,45]

Recreational Open Space

Recreational open space data come from the Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division, which is the state agency responsible for the collection, storage, and dissemination of publicly available geographic data for Massachusetts (http://www.mass.gov/mgis). This data layer used was updated as of late March 2012 and contains the boundaries of outdoor recreational facilities in Massachusetts, including parks, playing fields, school fields, and playgrounds, which could be privately or publicly owned facilities. Recreational open space per square kilometer for each census tract was calculated using ArcGIS version 10 (Environmental Systems Research Institute, Redlands, CA, US) in the Massachusetts state plane projection North American Datum 1983.

Population Density

We also measured population density, because it might influence the placement of recreational open spaces. Data on population density, which was downloaded from Social Explorer, come from the 2010 US Census, and it was operationalized as the total population per square kilometer.

SPATIAL ANALYSES

Following descriptive statistics, we evaluated the spatial relationship between minority neighborhood racial/ethnic composition, neighborhood poverty, and recreational open space. To evaluate this relationship, we designed a comprehensive spatial modeling approach including exploratory spatial data analysis and spatial regression modeling as appropriate.

Exploratory spatial data analysis first involved creation of GIS maps in ArcGIS 10 to evaluate the spatial distribution of our study variables (geovisualization); this facilitated an initial inspection of possible spatial patterns. Then, we computed the Global Moran's I to formally evaluate spatial patterns (or spatial autocorrelation).[28,29,46] We specified a row-standardized binary first-order Queen's contiguity spatial weights matrix for the Global Moran's I calculations, which defines neighbors as census tracts that share a common boundary or a corner. The Moran's I is the most commonly used test statistic for spatial autocorrelation and has a range of −1 (negative spatial autocorrelation, i.e., neighboring areas with large inverse values) to 1 (positive spatial autocorrelation, i.e., neighboring areas with similarly large or small values). A Moran's I value of 0 indicates no overall spatial autocorrelation or no overall spatial pattern; this is the null hypothesis of complete spatial randomness. To obtain a pseudo p value for the Moran's I values, we computed a Monte Carlo simulation of 999 random replications.

We computed correlations between the neighborhood socio-demographic characteristics and recreational open space density prior to regression analysis. Because the data had a non-normal distribution, we computed Spearman correlations. When spatial autocorrelation exists, the degrees of freedom in the conventional correlation tests of the significance may be incorrect, which can lead to misestimation of significance of effects[47–49] because spatial autocorrelation is a violation of the independence assumption. If necessary, we used the Clifford and Richardson adjustment method to account for spatial autocorrelation in the Spearman correlation coefficients, with six spatial lags used in generating correlation matrices based on the row-standardized first-order Queen contiguity weights matrix.[47,49] The sample size is adjusted, when using the Clifford and Richardson methodology, to account for the spatial dependence between observations. Based on the adjusted sample size, the corresponding t statistics and p values change. We report correlation coefficients (r_S) and significance values.

Because preliminary data analyses showed us that recreational open space density was highly skewed, we computed a natural logarithm transformation on recreational open space density, with a transformation offset of 0.001. For these log-linear models, we first computed ordinary least squares (OLS) regression models. We then computed spatial simultaneous autoregressive models, which are a well-known spatial econometric modeling approach,[26–30,50] if the OLS regression residuals had significant spatial autocorrelation. Specifically, we planned to estimate the spatial error model and the spatial lag model as appropriate. This is consistent with previous socio-demographic disparities in recreational neighborhood amenities research that implemented both spatial models.[18] The spatial error model accounts for spatial autocorrelation by including an autoregressive term for the error structure based on a specified spatial weights matrix whereas the spatial lag model accounts for spatial autocorrelation by including an autoregressive term for the outcome variable based on a specified spatial weights matrix.[26–30,50] The spatial model parameters were planned to be first estimated by maximum likelihood. Because we recognize that different techniques exist when estimating spatial linear regression models,[51] in a sensitivity analysis, we estimated the spatial models via other estimation methods such as the generalized method of moments technique for the spatial error model if spatial models were deemed appropriate.[51,52] The Global Moran's I statistic and the Lagrange Multiplier test for both spatial regression models were used to assess the fitted OLS regression residuals for evidence of spatial autocorrelation, using the row-standardized first-order Queen's spatial weights matrix.[26,30,50,53] The Global Moran's I statistic was applied to the error terms of the OLS model to evaluate spatial autocorrelation. The Lagrange Multiplier test for spatial lag and spatial error dependence is used when the Moran's I is statistically significant. The statistic with the highest value (and lowest p value) will indicate the proper specification for the data. If spatial models were necessary, the OLS and spatial model were compared using the Akaike Information Criterion (AIC), whereby a lower AIC value indicates a better model fit.[54] If spatial error models were fit, we conducted a spatial Hausman test comparing the magnitude of the OLS and spatial error model parameter estimates based on the null hypothesis of correct specification.[26,55]

We used the R statistical program and the *spdep* package for all spatial data analyses.[51] For these analyses, statistical significance was evaluated at $p<0.05$.

RESULTS

The mean density for recreational open space for our analytic sample of 167 census tracts was 0.039 (SD=0.045; range=0.000–0.224). The percent of census tract non-Hispanic Black, Hispanic, and families in poverty were 21.63 (SD=24.08), 17.70 (SD=14.78), and 15.54 (SD=14.81), respectively. Twenty out of the 167 census tracts were predominantly non-Hispanic Black; 5 out of the 167 census tracts were predominantly Hispanic, and 51 out of 167 census tracts were predominantly poor. The mean population density was 25,110.91 (SD=17,271.54).

The Moran's *I* for density of recreational open space was 0.082 (*p* value=0.053). The Moran's *I* values for the neighborhood socio-demographic characteristics were all positive but larger in magnitude than recreational open space density, and all of the neighborhood socio-demographic characteristics were statistically significant (all p values=0.001). For census tract predominantly non-Hispanic Black, the Moran's *I* value was 0.633 (p=0.001).

Although the *p* values were more conservative when spatial autocorrelation was accounted for when computing statistical significance of the Spearman correlations, findings substantively were similar (Table 1). The only significant correlation was found for Black neighborhoods. There was a negative correlation between census tract percent non-Hispanic Black and recreational open space density (r_S=–0.22; conventional *p* value=0.005; spatially adjusted *p* value=0.019) as well as a negative correlation between predominantly non-Hispanic Black census tracts and recreational open space density (r_S=–0.23; conventional *p* value=0.003; spatially adjusted *p* value=0.007).

Across the bivariate and multivariate models, the *p* value for the Global Moran's *I* for the residuals from the OLS regression models were not statistically significant, and the *p* values for the Lagrange Multiplier tests for the spatial models were similarly not statistically significant, all indicating that spatial models were not necessary. In the bivariate and multivariate OLS models, census tract percent non-Hispanic Black (a continuous variable) and predominantly non-Hispanic Black census tracts (a binary variable) were inversely associated with the log of recreational open space density ($p<0.001$) (Table 2). The magnitude of these associations was much larger when data were categorized as predominantly a racial/ethnic group than the continuous percentages.

TABLE 1 Spearman correlation between neighborhood-level socio-demographic characteristics and recreational open space density

	r_S	Conventional *p* value	Spatially adjusted *p* value
Percent non-Hispanic black	−0.216	0.005	0.019
Percent Hispanic	−0.072	0.356	0.430
Percent families in poverty	−0.074	0.339	0.387
Predominantly non-Hispanic black	−0.231	0.003	0.007
Predominantly Hispanic	0.042	0.587	–
Predominantly families in poverty	−0.043	0.577	0.609

Due to the small sample size of predominantly Hispanic neighborhoods, the spatially adjusted correlation between neighborhood predominantly Hispanic and recreational open space density could not be computed

TABLE 2 OLS model estimation of the relationship between neighborhood socio-demographic characteristics and log of recreational open space density

Bivariate estimation				Bivariate estimation			
	Coefficient	SE	*p*value		Coefficient	SE	*p*value
Percent non-Hispanic black	**−0.019**	**0.005**	<**0.001*****	Predominantly non-Hispanic Black	**−1.295**	**0.368**	<**0.001*****
Percent Hispanic	−0.003	0.008	0.691	Predominantly Hispanic	0.313	0.727	0.668
Percent families in poverty	−0.003	0.008	0.751	Predominantly families in poverty	−0.030	0.269	0.911

Multivariate estimation				Multivariate estimation			
	Coefficient	SE	*p*value		Coefficient	SE	*p*value
Percent non-Hispanic black	**−0.023**	**0.006**	<**0.001*****	Predominantly non-Hispanic Black	**−1.344**	**0.382**	<**0.001*****
Percent Hispanic	0.000	0.009	1.000	Predominantly Hispanic	0.220	0.718	0.760
Percent families in poverty	0.013	0.010	0.182	Predominantly families in poverty	0.163	0.268	0.543

*$p<0.05$ (bold); **$p<0.01$ (bold); ***$p<0.01$ (bold)

Multivariate models are controlled for population density and the other neighborhood socio-demographic characteristics

DISCUSSION

To the best of our knowledge, this is one of few studies that examine relationships between minority neighborhood racial/ethnic composition, neighborhood poverty, and the geography of recreation open space to have explicitly considered geospatial issues such as spatial autocorrelation and to consider threshold effects. We found spatial autocorrelation in the neighborhood socio-demographic characteristics, marginally significant spatial autocorrelation in recreational open space, and no spatial autocorrelation in the OLS regression residuals. Importantly, we found a negative correlation between census tract percent non-Hispanic Black and recreational open space density as well as a negative correlation between predominantly non-Hispanic Black census tracts (>60 % non-Hispanic Black in a census tract) and recreational open space density. We also found percent non-Hispanic Black in a census tract and predominantly Black census tracts were associated with decreased density of recreational open space. The magnitude of these associations was much larger when data were categorized as predominantly a racial/ethnic group than the continuous percentages, which suggests that there is a threshold effect. This study extends previous research by examining spatial autocorrelation and categorizing neighborhood composition as both continuous and categorical variables.

This study and our previous research found significant global spatial autocorrelation in neighborhood-level socio-demographic characteristics,[38] which confirms that there is racial and socioeconomic residential segregation in Boston.[13,56,57] To our knowledge, only a few studies have examined spatial clustering of recreational facilities, and these studies found significant positive spatial autocorrelation.[20,58–60] Of the studies that examine neighborhood socio-demographic disparities in recreational facilities, only a few have examined spatial autocorrelation in the OLS residuals.[18] Our main finding was neighborhood racial/ethnic composition disparities in recreational open spaces, which is consistent with the bulk of research conducted across neighborhoods in the US and some abroad that has found that minority neighborhood racial/ethnic composition is associated with reduced recreational open space and facilities.[18,21,22,61–65] To illustrate, Gordon-Larsen et al.[64] found high-minority neighborhoods were less likely to have physical activity facilities (the composite measure included parks and recreation camps) across US neighborhoods. It was unexpected that neighborhood racial composition would be only associated with recreational space. We expected to find effects for neighborhood poverty as well because several other studies found that socioeconomic disadvantage was associated with fewer recreational open spaces in neighborhoods.[19,21,61–63,65,66] Interestingly, our neighborhood poverty findings are similar to that of another study conducted in Boston. In multivariate models, Cradock et al.[40] found that neighborhood poverty was not associated with safety of neighborhood playgrounds (a different dimension of recreational access) while percent neighborhood Black was significant. A recent study among Boston youth found that Blacks were least likely to have recently used open spaces,[67] suggesting that access to open spaces is lower for Blacks. Together, these studies conducted in Boston on the spatial distribution of physical activity promoting neighborhood amenities suggest that race matters more than socioeconomic standing. It is important to note that as previously described, we restricted our analysis to census tracts with >500 people, which represents over 90 % of census tracts in Boston city. Several of the excluded census tracts have very few people (e.g., 22 people). Some of the excluded census tracts have a large degree of recreational open space density, and some are close in proximity to predominantly Black census tracts. Thus, in line with previous research,[22] Black neighborhoods might have "good" access to open spaces within walking distance (to a close-by census tract), although Black neighborhoods do have less acreage of open spaces.

Limitations of the Study

Data quality can be a concern when utilizing geospatial data,[68–70] as there can be errors of omission, features that no longer exist and positional errors. However, local GIS datasets may be less likely to have errors than national GIS datasets. We used a local GIS dataset on recreational open space in this research. The GIS layer evaluated was presence of recreational open space, which does not speak to quality of these amenities. Existing tools for examining quality of open spaces can be integrated into geospatial datasets.[71] While our categorization of high minority neighborhood racial/ethnic composition and high neighborhood poverty were based on previous research, we realized that other approaches to define these variables exist. For example, high minority neighborhood composition could be defined as 50 %, and high poverty neighborhoods could be defined as 30 % or more of the population living in poverty. These different categorizations could influence the findings from this study. Geographic research is often plagued with the modifiable areal unit problem.[72,73] Therefore, we recognize that the findings from this study are neighborhood unit-specific and that the results might be different if we used another spatial scale for example. However, census tracts are among one of the most common definitions in US research on socio-demographic disparities in neighborhood environmental features related to population health and community wellbeing. We also note that, although Boston-based neighborhood research has used census tracts,[34–38] other neighborhood definitions used in Boston include those based on the Boston Public Health Commission[41] and the Boston Redevelopment Authority,[74,75] but these neighborhood definitions are much larger than census tracts, and therefore, there probably is less variation among the units being measured due to spatial aggregation at coarser scales.[76] Census tracts that are adjacent to recreational open spaces outside of Boston are not accounted for in this analysis, suggesting the potential for "edge effects," which could lead to an underestimation of recreational open space access. However, our analysis focused on Boston. We also recognize that use of recreational open space access could be conceptualized in multiple ways, including accounting for pedestrian accidents and air pollution in evaluating the relationship between minority neighborhood racial/ethnic composition, neighborhood poverty, and recreational open space—as these other neighborhood features could dissuade people from using recreational open spaces.[77] However, we did not have information on these variables, and thus, residual confounding is a potential in this research. Because this study was conducted in a discrete geographic area, our results may only be generalizable similar urban cities.

Future Research

Future research should examine the relationship between minority neighborhood racial/ethnic composition, neighborhood poverty, and recreational open space in other geographies and using different definitions of neighborhoods, including further studies to see if the results are robust to smaller area specification and perhaps via egocentric neighborhood definitions.[78] Given that we were not able to conduct the analysis by type of recreational open space (due to the structure of the data), future research should consider conducting analyses disaggregated by type of recreational open space. Future research should also evaluate whether there are neighborhood socio-demographic disparities in *quality* of recreational open space in Boston and other areas. Indeed, parks and other open spaces can be a locale for violence and illegal activity (e.g., public intoxication or drug-dealing) and perhaps associated with increased by-products of drug-dealing (e.g., discarded syringes), resulting in a noxious open space environment. Also, it is possible that the parks in White neighborhoods have better conditions (e.g., less trash) than the parks in racial/ethnic minority neighborhoods. These open space disamenities could dissuade utilization of open spaces for people who have them in their neighborhood due to personal safety concerns, among other reasons. A qualitative study indicated that urban youths' concern about being intimidated by drug dealers reduced their park and other facility use.[79] Future research will inform comprehensive and effective policy recommendations.

Policy Implications of the Study

While additional research needs to be conducted, policy-level interventions should be considered to remedy disparities in access to recreational open spaces, including modifying urban and density zoning laws.[80] A proposed land use ideal is that a neighborhood should have at least 10 % of neighborhood land area dedicated to open spaces such as parks.[81] Implementing a 10 % neighborhood land area policy for open space could help remedy disparities in neighborhood open spaces and may be easier to implement than an urban planning policy specifically focused on remedying disparities. Research shows that, when parks are expanded, people use them[82]; these park expansion interventions may promote physical activity.[83] If possible, we still advocate for monitoring and evaluating potential disparities in neighborhood amenities such as parks and other recreational open space because even implementing a 10 % neighborhood land area policy for open space could worsen disparities. Furthermore, health impact assessments could be implemented to ameliorate the noxious health impact of segregation that are not traditionally evaluated in land use decisions[84,85] and could promote more equitable land use development, improvement, and expansion initiatives across neighborhoods.

Consistent with several previous studies in other geographic locales, we found that Black neighborhoods in Boston were less likely to have recreational open spaces, indicating the need for policy interventions promoting equitable access. Such interventions may contribute to reductions and disparities in obesity, but future research and intervention may be needed to ensure that quality of open spaces is also equitably distributed.

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