Title: Determining the Health Benefits of Green Space: Does gentrification matter?

Authors: Helen Cole[1,2], Margarita Triguero-Mas[1,2], James Connolly[1,2], Isabelle Anguelovski[1,2,3]

Affiliations:

1. Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona
2. Institut Hospital del Mar d'Investigacions Mèdiques
3. Institució Catalana de Recerca i Estudis Avançats

Corresponding Author Contact Information:
Helen Cole, DrPH
Institut de Ciència i Tecnologia Ambientals
Edifici Z (ICTA-ICP) - Carrer de les Columnes s/n - Office Z/146
Campus de la UAB · 08193 Bellaterra
(Cerdanyola del Vallès) · Barcelona · Spain
Email: helen.cole@uab.cat
Phone: +34 663574380

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Abstract

Urban green space is demonstrated to benefit human health. We evaluated whether neighborhood gentrification status matters when considering the health benefits of green space, and whether the benefits are received equitably across racial and socioeconomic groups. Greater exposure to active green space was significantly associated with lower odds of reporting fair or poor health, but only for those living in gentrifying neighborhoods. In gentrifying neighborhoods, only those with high education or high incomes benefited from neighborhood active green space. Structural interventions, such as new green space, should be planned and evaluated within the context of urban social inequity and change.

Keywords: Green space; self-rated health; gentrification; New York City; socioeconomic class; urban health

Introduction

Past literature and policy narratives on green space highlights the ecological, social, economic, and health benefits of interventions that increase access among urban residents. Yet, as planning for green cities becomes a widespread urban practice (Connolly, 2018), few have questioned specifically whose health benefits from greener cities. Such a question is important and timely in the context of an increasingly common link between greening and redevelopment in cities, and the associated wave of displacement, eviction, or erasure that socially or ethnically vulnerable residents are experiencing as a result of gentrification processes (Lees, 2012; Lees et al., 2008; Smith, 1996).

Historically, environmental amenities have been unequally distributed in cities, where privileged residents such as white, affluent communities, generally have better access to parks and other green spaces (Heynen et al., 2006; Wolch et al., 2014). Meanwhile, neighborhood crime, past experiences of violence in greenspace, the quality of spaces, and cultural norms, identities, and preferences also impact who ultimately uses these spaces and how, and therefore who may reap the health benefits of active use of green space (Agyeman et al., 2016; Anguelovski, 2014; Finney, 2014; Kabisch and Haase, 2014). Recent research points at "green gentrification", that is the creation of new patterns of unfair and inequitable distribution and allocation across space of socially valued resources — green amenities — within numerous and varied urban contexts (Isabelle Anguelovski et al., 2018; Checker, 2011). While new amenities accompanied by a crosscutting policy approach may have positive effects on the health of urban residents as a whole, environmental privilege (PARK and PELLOW, 2011)– that is the inequitable exposure to environmental amenities on the basis of social privilege – complicates these assumptions, particularly in the context of concentrated extreme wealth, income inequality, racial segregation, and general urban redevelopment trends (H. Cole et al., 2017). As a result, in this paper we ask who benefits from urban green amenities, and whether gentrification modifies the relationship between exposure to green spaces and health.

Green Space and Health

We refer to green space as a general term to include many types of publicly accessible green amenities (for example, urban parks, street trees, gardens, forests or agricultural lands) (Nieuwenhuijsen et al., 2014; Van den Berg et al., 2016). Exposure to green spaces has been linked to better health including: lower mortality (Donovan et al., 2013; Gascon et al., 2016; Shen and Lung, 2016; Villeneuve et al., 2012), and better self-reported general and mental health (Carter and Horwitz, 2014; Gascon et al., 2015; Reklaitiene et al., 2014; Triguero-Mas et al., 2015). For instance, a cohort study on access to and use of green space in Europe has revealed that cardiovascular risk factors and diabetes are significantly lower among residents visiting parks than among those who do not (Tamosiunas et al., 2014).

Meanwhile, past research documents that health status varies by socioeconomic status and other social stratification measures, such as race. In the United States, inequities in health outcomes by race and socioeconomic status persist, and by some reports are growing (Singh et al., 2015). This is especially the case in cities (Friel et al., 2011) despite decades of focus on creating healthy cities for all by the public health and urban planning communities. Members of vulnerable groups, such as racial or ethnic minorities, and those with low socioeconomic status, have a significantly shorter life expectancy and greater burden of chronic disease outcomes, than their non-vulnerable peers (Singh et al., 2017, 2015). These inequities manifest spatially due to historic and persisting racial and social segregation patterns, resulting in uneven health outcomes and life expectancy across neighborhoods (Dwyer-Lindgren et al., 2017). It has been suggested that these neighborhood differences are shaped in part by the natural and built environments which vary by neighborhood, such as exposure to green space and aspects of the social environment.

Although the prevailing trend in existing literature is that lower socioeconomic status individuals may benefit more from exposure to green space (Maas et al., 2006)(Dadvand et al., 2014; McEachan et al., 2016; Triguero-Mas et al., 2017; Van den Berg et al., 2016), at least one study has found that vulnerable groups such as those with low levels of education benefit less (Pun et al., 2018). Similarly, one past study found that income inequalities in rates of overall mortality and mortality due to circulatory disease were lower in greener areas (Mitchell and Popham, 2008). Past research has similarly found that the relationship between green space and health varies by race/ethnicity. One study among older adults in the U.S. found that while there was a significant negative relationship between greenness and anxiety and greenness and depression, this relationship did not hold for minority other races or ethnic groups (Pun et al., 2018). One explanation for these findings is that fear and anxiety connected to green space may exclude minorities, particularly blacks in the United States, from benefiting from green space due to the legacy of exclusion and violence associated with these spaces.

Gentrification

Gentrification is defined as a process of neighborhood change through which the demographic, real estate, and business characteristics of a place reveal a transition towards a more educated, wealthy, whiter population, able to afford new or renovated pricier properties while also fomenting new cultural and consumption practices (Lees et al., 2015; Smith, 1996, 1982). Over the past several decades, scholars have debated whether gentrification is harmful for lower class residents, potentially causing physical or cultural displacement, or increased financial pressures due to increasing costs of living in such neighborhoods, or whether it may also be seen as beneficial, potentially leading to greater employment opportunities (Meltzer and Ghorbani, 2017) or lower crime rates,(Papachristos et al., 2011). One particular argument, supported by evidence that gentrification may not necessarily result in displacement (Freeman, 2005), is that social mix brought on by an influx of wealthier residents may lead to social mobility for lower class residents of gentrifying neighborhoods. In existing research, various qualitative and quantitative methods have been employed to test such hypotheses. Quantitative approaches to measuring gentrification use a set of socioeconomic and real estate indicators – including income, ethnicity, race, education, occupational status, age, tenure status, housing/rental prices and capital investment (Atkinson, 2000; Freeman and Braconi, 2004; Glick, 2008; Hammel and Wyly, 1996) – to identify areas where these characteristics have changed at the census tract or neighborhood level more quickly than for the city (or some other comparison geography) as a whole. Qualitatively, gentrification is often characterized by cultural displacement processes, and can even be accompanied by physical displacement (Marcuse, 1985) and by a sense of loss, displacement and erasure for long-term residents (Shaw and Hagemans, 2015)(Anguelovski et al., n.d.; Fullilove, 2001).

Gentrification and Health

While several hypotheses exist relating to the potential effects of gentrification on health (“Health Effects of Gentrification,” 2009) , few empirical studies to date have investigated these links (Mehdipanah et al., 2017). Emerging literature documents a trend toward a differential effect of gentrification on health by group membership, where those belonging to the lower socioeconomic classes may not benefit, even when benefit is seen among more dominant groups or residents of gentrifying neighborhoods at large. For example, Gibbons and Barton (Gibbons and Barton, 2016) found that while living in gentrifying neighborhoods was linked to better perceived general health for the population as a whole, the opposite relationship was found for black communities. Similarly, Huynh and Maroko (Huynh and Maroko, 2014) found that living in a highly gentrified neighborhood was significantly associated with pre-term birth among non-Hispanic (NH) black women, whereas living in a highly gentrified neighborhood had a protective effect among NH white women. Among medically vulnerable urban communities, residential displacement, often associated with gentrification trends, may have negative impacts on access to healthcare and on mental health (Lim et al., 2017). Fear of displacement is also associated with psychological distress (Pearsall, 2012), and this may contribute to poor health outcomes. Similarly, the feeling of being out of place and unwelcome in a changing neighborhood (e.g. changes in types of amenities in the neighborhood like from "mom and pop" to chain stores and restaurants (Anguelovski, 2015)) have been linked to anxiety.

To date no studies have investigated the interaction between gentrification processes and other aspects of the social or physical environments of cities commonly cited in the realm of "healthy cities", such as urban greening. Addressing this research gap is particularly timely as cities are increasingly mobilizing greening to address environmental impacts, promote economic growth, create jobs, and enhance social cohesion and other well-being and health objectives (Anguelovski et al., n.d.; Connolly, 2018).

Specific Aims

We investigate the relationship between exposure to green space and health and assess whether evidence of gentrification modifies this relationship. We narrow our focus to active green space, which we define as green areas designated specifically for active use by residents (i.e. walkways, greenways, parks, etc.) in order align with aforementioned hypotheses regarding the mechanisms by which green space may improve health. We aim to explore the association between exposure to green space and health from an equity perspective, and respond to calls for research on the health effects associated with the complex relationship between environmental amenities and neighborhood changes such as gentrification (H. V. S. Cole et al., 2017). To do so, we assessed whether: (a) there was an association between exposure to active green space and general self-rated health, (b) the association was modified by neighborhood gentrification status, and within each type of neighborhood (wealthy, non-gentrifying, or gentrifying), (c) individual-level sociodemographic characteristics.

Methods

Data Sources and Measures

We used data from New York City, a city with ample evidence of gentrification since the 1990s, a strong history of greening, and numerous recent urban green spaces that have garnered community resistance due to concerns of gentrification (Checker, 2011; Connolly, 2018; Pearsall, 2013). We used three primary sources of data: 1) individual-level health and demographic data by ZIP Code area from the New York City Department of Health and Mental Hygiene Community Health Survey (CHS) from the years 2009 to 2013, 2) green spatial data from the New York City Department of Parks and Recreation, and 3) gentrification measures from US Census Bureau using census data from the years 2000 and the American Community Survey for 2006-2010.

Health Outcome Data

The CHS is conducted annually among approximately 10,000 New York City residents ages 18 and older using a stratified random sampling strategy to estimate rates of health-related indicators for the general population of the city. For estimates at the smaller geography of ZIP codes, the data were aggregated over 5 years. We used the CHS data for 2009-2013 with ZIP code areas for each respondent. For ZIP codes with populations of less than 30,000, adjoining ZIP codes were aggregated. We refer to the ZIP Codes and ZIP code groups as ZCTAs (ZIP code Tabulation Areas). We focused on self-rated general health at the individual level from the CHS. This was measured using a standard question commonly used in health surveillance and research, which asks each participant to rate their health on a 5-point likert scale: excellent, very good, good, fair or poor. The measure was then dichotomized, classifying those who responded with fair or poor together, compared to those in the other three categories. Although this is a self-reported measure, this method of measuring general health has been shown to have strong predictive validity for mortality (Schnittker and Bacak, 2014).

Access to Green Space

Past studies on green space have used many different methods of exposure, and this has been a subject of debate in the literature (Smith et al., 2017). Here, we chose to focus on active green public space to align with hypothesized mediating pathways such as the encouragement of physical activity, positive social interactions, and prolonged contact with nature, for which broader measures such as NDVI may not be appropriate (I. Anguelovski et al., 2018). Active public spaces have also been the focus of much gentrification research, particularly changes in who has accesses and uses public spaces for socialization (Wolch et al., 2014). In New York City, these included: waterfront walkways, public recreation fields, parks, accessible preserves where people can hike, and community gardens.

In keeping with past research investigating the health effects of green space at by ZCTA in New York City (Stark et al., 2014), we calculated green space exposures using buffers of 400 meters around each ZCTA, calculated using ArcGIS software. This buffer size selected following precedence from past studies, which justify 400 meters as an appropriate walking distance (Stark et al., 2014). We used a 2017 complete inventory of publicly owned park properties acquired from the City of New York open data portal and removed properties acquisitioned after 2008 to match the exposure with the timing of the health data. Next, all spaces were manually classified by type and only those with active public uses (i.e., waterfront walkways, public recreation fields, parks, accessible preserves where people can hike, and community gardens) were retained. We then calculated the percent of each ZCTA area (including the buffer) which was designated for active open public green space.

Gentrification

All census and ACS variables were downloaded at the census tract level, normalized to the 2010 census tract boundaries by Geolytics, Inc, presented as count data. We calculated proportions for each variable at the ZCTA level and, separately, for the city as a whole. We then calculated percent change between 2000 and 2006 to 2010 for each area. We used change in the following census and ACS variables as potential indicators of gentrification: percentage of high and low income populations (determined using a threshold of 80% of median household income calculated by HUD for low income, and 125% of the same value as a threshold for high income); percentage of minority, non-white populations; change in percentage of population with a college degree or higher; percentage of population working in a professional occupation; percentage of households paying more than 125% of the city-wide median rent; and percentage of young adults. In considering these indicators, we consulted reports from the New York University Furman Center on gentrification in the city (AUSTENSEN et al., 2016) along with the general literature about gentrification.

To reduce potential bias in calculating gentrification measures by ZCTA, given that the census data used, which is normalized to the 2010 tract boundaries across all years, is released in tract boundaries, not zipcodes (a larger geographic area, but one that does not match the boundaries of combined census tracts), we used lot-level data from PLUTO (Property Land Use Tax lot Output- parcel level data) as the weight in order to perform a dasymetric reapportionment of census data from tract to the specific ZCTA areas used by the CHS. This was necessary to retain a standard geography across all years within the study. From the PLUTO file, we extracted residential floor area per parcel, which we used to weight parcels within each census tract. For parcels where the number of residential units was 0 but residential floor area was greater than 0, we excluded the residential floor area for the building, as these buildings were probably under construction or otherwise uninhabited (such as office buildings). Census tract data for indicators of gentrification reapportioned to lots based on these weights was then re-aggregated using the boundaries of the ZCTAs.

We first identified ZCTAs where more than half of the population fell into the low-income category according to the 2000 census data, and considered these as "gentrifiable", similar to the methods used by past researchers (Gibbons and Barton, 2016). Among those zip codes, as in a past study in Barcelona (Isabelle Anguelovski et al., 2018), we calculated a gentrification score by first comparing rates of change within zip code areas to the city-wide change over the same time period. If the rate of change between 2000 and 2006 to 2010 was greater for the zip code than for the city, we counted this as one indicator of gentrification. For indicators representing a change in socially vulnerable residents, such as percentage of low-income or minority residents, we reversed the coding such that a lower change in the percentage of these populations in 2006 to 2010 was considered an indicator of gentrification. For each zip code, we then summed the number of indicators of gentrification. We considered those zip codes in which 4 or more indicators of gentrification were present to have strong evidence of gentrification, since gentrification researchers tend to agree about the fact that gentrification trends are occurring only if several indicators of gentrification move in the gentrification direction (Isabelle Anguelovski et al., 2018; Glick, 2008; Hammel and Wyly, 1996). The group of zip codes where gentrification was not happening was divided in two groups, as in past research (Lim et al., 2017): neighborhoods with low gentrification scores due to a high baseline level of wealth and privilege (wealthy neighborhoods) and neighborhoods where disinvestment and a high percentage of vulnerable residents has remained through 2010 (gentrifiable, but with no evidence of gentrifying). Thus, our classification scheme counted ZCTAs as being: 1) wealthy, non-gentrifying, 2) gentrifiable but not gentrifying, or 3) gentrifying.

Control Variables

To account for individual-level demographic characteristics and neighborhood characteristics which are salient for the study of neighborhood health and may confound our results, we employed both individual-level variables from the CHS and neighborhood-level indicators derived from the census variables at the ZCTA level. Specifically, we adjusted all models for individual-level age, sex, race/ethnicity, marital status (dichotomized as married vs not married), education level, and poverty (as a percentage of the federal poverty level). We used American Community Survey data from 2006-2010 to calculate control measures at the neighborhood-level. These included: 1) proportion of poverty at the zip code level and 2) racial segregation, using the Index of Concentration at the Extreme measure developed by Douglass Massey (Massey, 1996).

Statistical Analysis

Participants were excluded from all analyses if they were missing ZCTA data (n=721), and final regression models included only participants who had data for all independent variables (n=40,247). We conducted descriptive and regression analyses using the *svy* command to account for the structure of the health survey data adjusting for survey strata and an individual weight variable provided with the dataset, weighting the sample to the NYC adult residential population by ZCTA as calculated by the American Community Survey, 2009-2013. We used logistic regression modeling with the *svy* command to test our hypotheses. We adjusted all models for age, race/ethnicity, sex, income level, education level, marital status, nativity, neighborhood-level poverty, and neighborhood segregation. We used STATA, version 14.0 and set statistical significance at p-value<0.05.

<u>Green spaces and health</u>

In the first model, we tested whether, after adjusting for control variables, there was a significant relationship between level of active green space and self-rated health among the full sample.

<u>Green spaces, neighborhood gentrification and health</u>

In the second model, we then added neighborhood gentrifications status to the model.

<u>Effect modification by neighborhood gentrification</u>

In our next model, we tested interaction terms for gentrification and active green space, testing the null hypothesis of homogeneity (i.e. $\exp(\beta_{\text{factor of interest}}) = \exp(\exp(\beta_{\text{factor of interest}} + \beta_{\text{exposure}}))$, using the *testparm* command to conduct a Wald test for overall significance for the interaction. The sample was then stratified by neighborhood gentrification status (as the interaction term was found to be significant). Finally, we used the *margins* command to calculate predicted probability of reporting fair or poor health by quartile of neighborhood active green space and gentrification status.

Effect modification by social vulnerability

We also tested interaction terms for three measures of social vulnerability (race/ethnicity, education, and income) and active green space, testing the null hypothesis of homogeneity and a Wald test for overall significance for the interaction for race/ethnicity. For measures with significant interaction terms, we then conducted stratified models.

Effect modification by neighborhood gentrification and social vulnerability

Among models stratified by gentrification, we then explored if the effect of exposure to active green space on self-rated health varied by socially vulnerable subgroup (i.e. by race/ethnicity, by education, and by poverty group). For those cases where the null hypothesis of was rejected in bivariate interactions or by the Wald test, we then stratified the sample, testing each subgroup independently. For race/ethnicity, we ran stratified models for all groups except “NH other race” as this group is a catch-all category for which results would be impossible to interpret in the broader social context. For education level and poverty level, we identified the most “privileged” strata (i.e., those with at least a college education and those with an income at least 400% of federal poverty level).

Results

Analyses included all participants from the CHS with valid ZCTA data, a total of 44,167 participants in the 5 years of the CHS data. Demographic data and ZCTA characteristics, for the entire sample and stratified by level of active green space, for all participants is presented in Table 1. The overall average percentage of active green space per ZCTA was 9.5%. Residents of ZCTAs with a high level vs low level of active green space available were more likely to be older ($p<0.05$); NH white, Hispanic or other race ($p<0.05$); have a higher level of education ($p<0.05$); be in a higher income category ($p<0.05$); and be native-born ($p<0.05$). A map of percentage of active green space per ZCTA, noting which ZCTAs were considered gentrifying, along with the percentage NH black population is presented in Figure 1.

Green spaces and health

When exploring the association between green spaces and health, adjusted for individual demographic characteristics as well as neighborhood-level poverty and racial segregation, we found that higher green space exposure was associated with 47% lower likelihood of poor health (coefficients in Table 2, Model 1).

Green spaces, gentrification and health

After adjusting for gentrification, the relationship between green space exposure and likelihood of reporting poor health was no longer significant (see coefficients in Table 2, Model 2). In addition, compared to living in an already wealthy neighborhood, living in non-gentrifying neighborhoods or gentrifying neighborhoods was linked to around 50% higher likelihood of reporting poor health, independent of the level of neighborhood active green space (see Table 2, Model 2).

Effect modification by neighborhood gentrification

A significant interaction between neighborhood gentrification status and active green space was found (see Table 2, Model 2a, Wald p-value<0.05). Stratified models by neighborhood gentrification status revealed that the significant relationship between exposure to active green space and lower likelihood of reporting fair or poor health remained only for residents of gentrifying neighborhoods (aOR=0.13, CI 0.03 to 0.59, p<0.05; see coefficients in Figure 2a). Using the regression model to calculate predicted probabilities of reporting fair or poor health, we find that while the predicted probability of reporting fair or poor health among those living in non-gentrifying neighborhoods (between 0.23 and 0.24) and wealthy neighborhoods (between 0.17 and 0.19) remained similar across levels of neighborhood active green space, those living in gentrifying neighborhoods would expect almost a 0.07 decrease in the probability of reporting fair or poor health between those living in areas with the lowest level of active green space (probability=0.26) and the highest (probability=0.19; Figure 3).

Effect modification by social vulnerability

We found significant interactions between race/ethnicity and active green space (Wald p-value<0.05), and between level of education and active green space (p<0.05). Using stratified samples, we found that the association between reporting fair or poor health and active green space remained significant only for non-Hispanic white individuals (aOR=0.32, CI 0.14 to 0.72, p<0.05) and those with at least a college degree (aOR=0.17, CI 0.07 to 0.40, p<0.05), but not for other racial/ethnic categories or those with a lower level of education (see coefficients in Figures 2b and 2c).

Effect modification by neighborhood gentrification and social vulnerability

Among residents of gentrifying neighborhoods, we then tested three interaction terms in separate models: active green space and race/ethnicity, active green space and college education or greater and active green space and incomes of at least 400% of federal poverty level. As the race/ethnicity variable had multiple categories, we calculated a regression coefficient for each category and tested overall significance of the interaction term using a Wald test, finding a significance of $p<0.05$. We also found significant interaction terms ($p<0.05$) for college education and having an income of 400% of federal poverty or greater (see Table 3, Models 3a, 3b, 3c).

Finally, in models for those living in gentrifying neighborhoods, stratifying by socioeconomic status and race/ethnicity, we found that the significant negative relationship between active green space and reporting fair or poor health held only for those with at least a college degree (aOR=0.01, CI 0.00 to 0.29, $p<0.05$) and those with incomes at least 400% of poverty level (aOR=0.003, CI 0.00 to 0.23) For all other strata, there was no significant effect of active green space on self-rated health (see regression coefficients in Figure 4).

Discussion

Higher exposure to green spaces was associated with lower likelihood of reporting fair or poor health. We also found indications that the effect of active green space on self-reported health varied by neighborhood gentrification status, and by social vulnerability indicators. We found no significant benefit for any specific racial/ethnic group living in gentrifying neighborhoods. However, we found that in gentrifying neighborhoods only those with high socioeconomic status (high education or income) benefited from exposure to green spaces.

How does living in areas with active green space affect general health?

For the entire sample a significant negative relationship existed between level of ZCTA active green space and fair or poor health. However, when including gentrification in our model, we found that the association with green spaces exposure disappeared, indicating the salience of gentrification in predicting poor or fair general health and that its influence may mask the affect of green space. We found that living in a non-gentrifying or gentrifying neighborhoods was associated to a higher likelihood of reporting fair or poor health than living in a non-gentrifying wealthy neighborhood.

Do all residents benefit equitably from active green space?

Informed by past literature demonstrating the differential health effect green space by social class and race (Dadvand et al., 2014; Pun et al., 2018), we conducted separate analyses for each sub-population, testing for which groups the positive effects of active green space on self-rated health remained. Here, we find that the positive effect of active green space on general health holds only for non-Hispanic Whites, and for those with higher levels of education independent of neighborhood gentrification status. No such relationship exists for other races/ethnicities or those with lower levels of education. There are several potential explanatory pathways for this finding.

Hypothesized mechanisms by which exposure to green space benefits health include both active use of such spaces (i.e., the use of parks for physical activity or to promote positive social interactions among park users) and ambient exposure to fewer environmental toxins such as air pollution or temperature. We can assume that the effects of ambient exposures are distributed amongst all residents in a given area, as active use does not determine exposure. However, in terms of active use of parks, a growing body of research from the leisure sciences and urban geography attempts to explain whether and why members of certain social groups may either be less likely to visit parks (Das et al., 2017; Finney, 2014; Kabisch and Haase, 2014) or to be less likely to use them for active recreation (Derose et al., 2015). Explanations for differences in park use by race, for example, describe the historical meaning of such spaces for certain groups such as the historical association of open space with lynching, or associations with other types of violence (Agyeman et al., 2016; Finney, 2014). Thus, it is not surprising that our findings indicate a difference in health benefits of active green space exposure by race/ethnicity and level of education across ZCTAs.

Prevailing trends from past research has shown the opposite relationship, that those of lower socioeconomic status may benefit more from living near green spaces, although a few studies have found, more in line with our results, that minorities or those with lower levels of education benefit less (Dadvand et al., 2014; de Vries et al., 2003; Pun et al., 2018). These studies provide little analysis of why these differences may be observed, hypothesizing only that it may have to do more with time spent in one's neighborhood, which may vary by socioeconomic status or minority group, especially among specific groups like pregnant women with low levels of education (Dadvand et al., 2014). It could also be that those with lower socioeconomic status or of minority race/ethnicity may have worse health in general, whereas more privileged groups may experience a ceiling effect in benefit. In contrast, our results fit with the broader understanding of social tensions and inequality in cities, and particularly within the social history of race in American cities.

Do all residents of gentrifying neighborhoods benefit equitably from active green space?

We find significant negative relationship between active green space and poor or fair health only among those living in gentrifying neighborhoods. This would indicate that gentrification may amplify the benefit of active green space. However, among those living in gentrifying neighborhoods, our results indicate that the apparent benefit of active green space is driven by the experiences of high income and highly educated residents (i.e., gentrifiers). Meanwhile, those with lower levels of education and income did not appear to benefit, even in gentrifying neighborhoods.

We did not find evidence that benefit may vary by race in gentrified neighborhoods. In our stratified analyses among only residents of gentrifying neighborhoods, no single race/ethnic group maintained a benefit of active green space. This may be explained by within-race difference in health status and experience of social exclusion. For example, among NH black residents, particularly in urban areas like New York City, substantial variation exists in nativity or ethnicity, and this may mask differences in outcomes by broad, heterogeneous racial/ethnic categories. While minority residents are found in past studies on gentrification and health to benefit least from gentrification, these studies have varied greatly in terms of population studied. One taking place in New York City focused on pregnant women, a group which may have more in common than all adult representatives of heterogeneous racial and ethnic groups (Huynh and Maroko, 2014). In contrast, our measures of socioeconomic status (namely, income and education) would not vary significantly within each sub-group.

An additional concern for the health of poor and minority residents living in gentrifying neighborhoods is the potential for social, cultural or physical displacement due to neighborhood changes associated with gentrification such as rising prices of rent, lack of affordability in general, and changes to the cultural environment of a neighborhood resulting in social exclusion (Fullilove, 2001; Marcuse, 1986). The result of these disparities since the 1990s has been widespread examples of gentrification in cities. Our results show that social exclusion contributes to determining who benefits from the exposure to urban active green space and who does not, where those who do benefit are those among the “gentrifiers” (i.e., those with high levels of education and income).

Limitations and future research

Several challenges in the quantification of indicators used in this study may have biased study results. First, health data at the individual level was available only for 5 consecutive years aggregated , and this does not allow us to study trends over time therefore further limiting our ability to test causal inference. However, a strength of our study is that, by aggregating 5 years of data, our sample included over 40,000 New York City residents, which allowed us ample power to test our hypotheses. In addition, the survey is conducted annually and meant to represent the adult population of New York City, and survey weights allowed us to further adjust for the representativeness of the sample, more accurately accounting for the disadvantaged groups and more likely to experience worse health outcomes.

Secondly, the health data was presented only at the ZCTA geography, a relatively large geographic area, which limited our accuracy in ability to measure exposure to green space and gentrification for individual participants. Future research should also consider the length of residency in a neighborhood, and the level and type of park use and its characteristics, either subjective or objective, in order to further specify and contextualize the amount of exposure. Here the large sample size also helped to overcome this weakness. In addition, we used dasymetric reapportioning techniques to increase accuracy for ZCTA level gentrification measures derived from the US census and American Community Survey. Our use of ZCTA as the level of exposure also omits exposures experienced away from ones’ own neighborhood- such as the use of parks in other parts of the city. In addition, it deserves note that this study was not designed to take into account spatial clustering, a phenomenon that reflects the nature of urbanization, and of urban processes such as gentrification, and this may also have biased study results. We have applied several statistical controls for aspects of the neighborhood social environment (segregation and neighborhood-level income) and a survey command to adjust the sample to the overall population of New York City.

Furthermore, gentrification is a complex process which is still being characterized by social scientists and is impossible to capture in all of its complexity within quantitative data, thus our indicators are a somewhat rough estimation. To increase our accuracy within these constraints, we reviewed several methods used in past studies for measuring gentrification and balanced these with available data for our study in determining our measurement. As many iconic examples of both generally gentrifying and green gentrifying neighborhoods come from New York City, it is also notable that the geography of gentrification that we found corresponds with prior studies, both quantitative and qualitative.

Although the body of literature around gentrification and health is growing as public interest and attention to the phenomenon increases, much remains to be known about the best methods for measuring gentrification for quantitative research. The Furman Center (AUSTENSEN et al., 2016) for example, bases their measurement of gentrification entirely on changes in rental prices, and conceptualizes additional changes in demographic characteristics as resulting changes of the process. We considered any change in the given demographic or socioeconomic measures identified as indicative of gentrification processes as part of the measurement. We thought of the neighborhood as a holistic environment with multiple parallel characteristics indicating gentrification, including those not specific to displacement. Due to feasibility restraints, also missing in our estimation of gentrification are measures of non-population-based changes, particularly changes to the built environment such as the presence of new types of businesses or up-scale developments (among others). Given that the social histories and environment of each city varies, by extension no one measure of gentrification may fit all analyses or settings. As the process of gentrification expands beyond iconic big cities, along with the increase of urbanization and social inequity in cities, further research into both the measurement of gentrification and the methods available to understand the effect of large-scale neighborhood change on health is needed.

Policy and planning implications

Throughout cities in the United States and beyond, municipal urban planning departments aim to expand green space in cities and acknowledge concerns for equity and for improving access to parks for all residents, especially those with historically less access. In fact, we saw that NH black, NH Asian, and other race residents were more likely to live in zip codes with a lower percentage of active green space. However, our study also showed that while greater percentage of active green space was significantly negatively associated with reporting fair or poor health, among those with a lower level of education and those of minority race/ethnicity, there was no association between green space and improved general self-rated health. While goals of improved green space access to underserved neighborhoods may be driven by the benevolent concerns for resident health and well-being, cities must also consider the preference and needs of residents, such as how to design parks that meet the needs of various groups of residents, consider their historic perceptions of a neighborhood space or of green spaces in general, and reflect their overall socio-cultural identity. Only then might all residents benefit equally from urban green spaces.

Furthermore, the use of park space as a public health or urban planning intervention has the potential to result in green gentrification (Checker, 2011; Gould and Lewis, 2016), defined as combined dynamics of land revaluation, greening, and displacement (Checker, 2011; Dooling, 2009). At the same time, the debate over whether gentrification displaces or replaces original residents (Marcuse, 1985; Newman and Wyly, 2006) is still ongoing (Zuk et al., 2018). Our results indicate that the development of new parks and open space, which are often established with the stated goal of benefiting the health of urban residents, must take into account both the potential that not all residents benefit equitably and that the potential unintentional (or unstated) consequences of such large-scale physical interventions on the social environments in cities (such as gentrification) have important implications for who benefits, and who does not benefit from such spaces. Assessing the implementation of interventions involving change to the physical environment should take into account a broader understanding of the social changes that may also result from such amenities, and the potential consequences for social and health inequity.

Conclusions

Within the complex social and environmental composition of US neighborhoods, the known positive relationship between exposure to urban green space and good health varies by race/ethnicity, level of education, and by neighborhood gentrification. This may reflect the difference in the experiences of people living in a socially and racially stratified and inequitable society, and the lasting effects of racial and social bias and segregation. While active green space appears to benefit health, this was only the case in gentrifying neighborhoods. Meanwhile, among those living in gentrifying neighborhoods, only those with at least a college degree and those with higher incomes seemed to benefit from active green space, whereas there were no health benefits for those with lower incomes and lower levels of education. In other words, gentrification does not – as some champions of gentrification argue – bring benefits normally afforded only to the dominant race or social class (i.e., the gentrifiers) to those among the subaltern. The benefits of active green space on health are not equitably distributed and there is no health benefit spillover across social divides as a result of gentrification.

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Table 1: Individual-level demographic and health characteristics (N=44,167) and zip-code characteristics (N=128) by percentage of zip-code active green space, 2009-2013 data are weighted to the NYC adult residential population as per the American Community Survey, 2009-2013

Demographics	N	Total	Living in ZCTAs with Active Green Space Below the City Median	Living in ZCTAs with Active Green Space Equal to or Above the city Median	p-value
Women	44,167	54.0%	53.6%	54.4%	0.276
Age	44,084				<0.001
18-24		12.9%	12.8%	13.0%	
25-44		40.1%	42.5%	38.4%	
45-64		31.7%	30.4%	32.8%	
65+		15.4%	15.1%	15.8%	
Race/Ethnicity	44,167				<0.001
NH White		36.0%	34.8%	37.4%	
NH black		22.3%	24.0%	20.3%	
Hispanic		26.3%	23.5%	29.6%	
NH Asian		13.3%	15.4%	10.8%	
Other		2.1%	2.3%	1.9%	
Education	43,915				0.004
Less than high school		16.3%	16.5%	16.1%	
High school		26.9%	27.9%	25.9%	
Some university		23.6%	23.4%	23.7%	
University degree or higher		33.2%	32.2%	34.3%	
Household poverty	41,118				<0.001
<200% FPL		43.3%	45.9%	41.5%	
200-<400% FPL		15.3%	14.8%	15.9%	
400%+		30.9%	29.3%	32.7%	
Unknown		10.5%	10.9%	9.9%	
Foreign-born	43,987	46.3%	49.2%	43.0%	<0.001
Married	43,811	41.9%	42.0%	41.7%	0.727
Health Outcomes					
Poor or fair health	43,853	21.3%	21.9%	20.6%	0.026
Zip Code Characteristics		Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	
% Active green space	128	9.5 (8.1-10.9)	3.5 (2.9-4.0)	16.2 (14.5-17.8)	<0.001
Poverty level	128	18.7 (17.2-20.2)	18.2 (16.2-20.2)	19.2 (17.0-21.4)	0.506
Racial segregation (ICE)	128	0.13 (0.05-0.22)	0.13 (0.01-0.25)	0.14 (0.02-0.25)	0.975
Gentrification	128				0.772
Wealthy		10.0 (8.0-12.1)	3.7 (2.9-4.6)	16.7 (14.3-19.1)	
Non-gentrifying		9.2 (6.8-11.5)	3.1 (1.9-4.2)	15.3 (12.5-18.1)	
Gentrifying		8.7 (5.1-12.3)	3.5 (2.2-4.8)	16.5 (11.2-21.8)	

Figure 1: Level of active green space by ZCTA area, where dots indicate the NH black population, and ZCTAs with dark borders are classified as gentrifying.

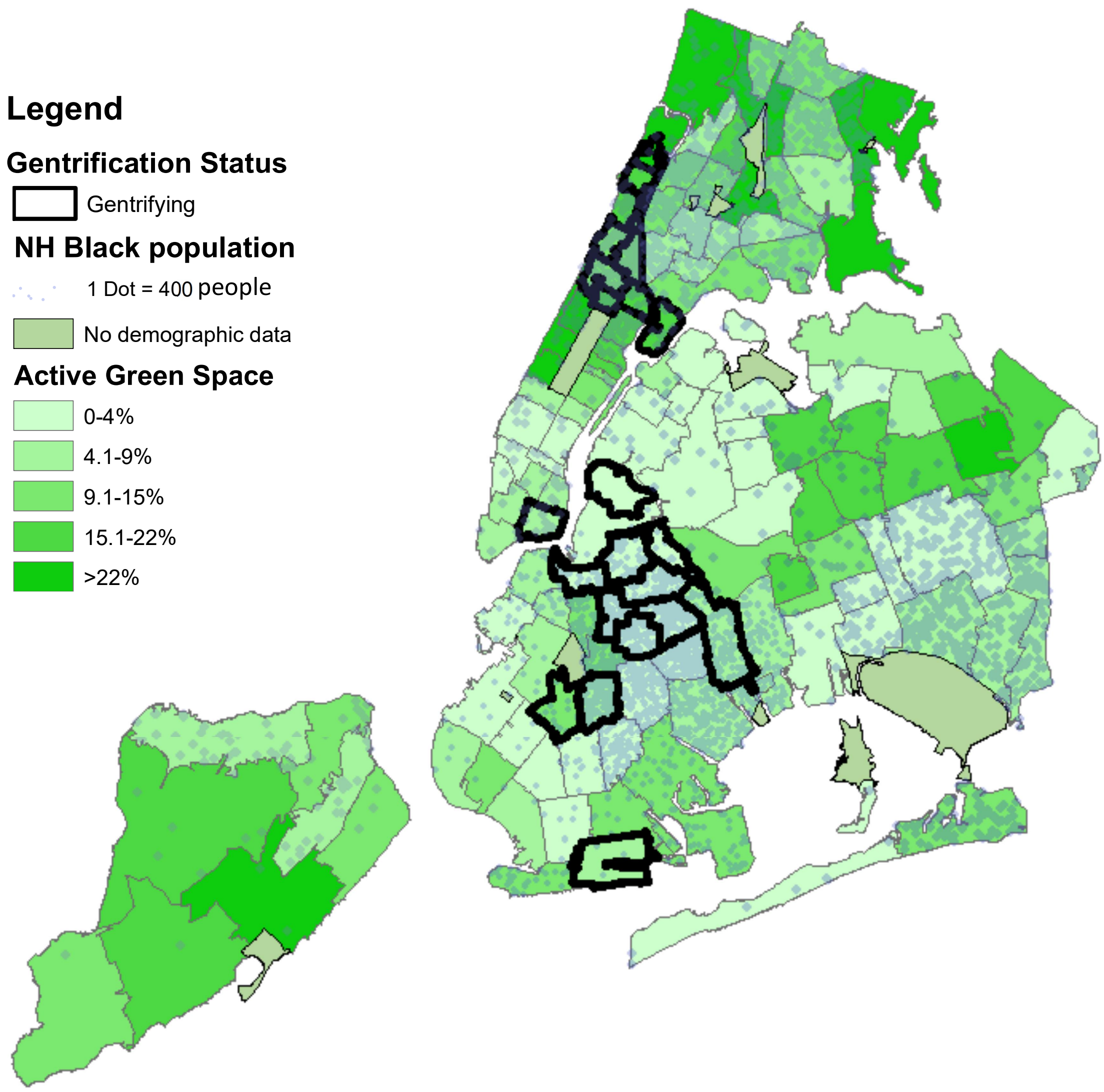


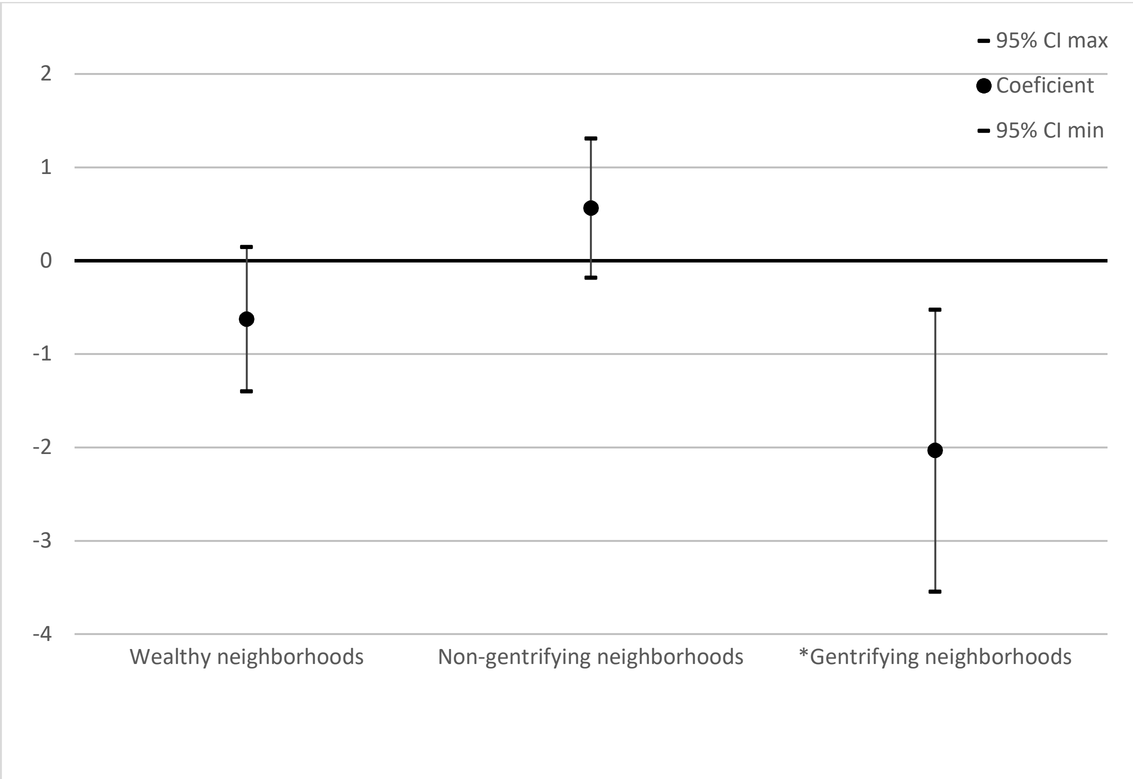
Table 2: Logistic regression coefficients from models testing the relationship between green space and self-reported poor or fair health. All models are adjusted for age, gender, race/ethnicity, education, individual poverty level, marital status, neighborhood segregation, and neighborhood-level poverty.

	Coef	95% CI	p-value
Model 1: Green spaces and health			
Active green space	**-0.64**	**(-1.27, -.14)**	**<0.05**
Model 2: Green space, gentrification and health			
Active green space	-0.38	(-0.89, 0.12)	0.136
Neighborhood Gentrification (ref=non-gentrifying wealthy)			
Non-gentrifying	**0.38**	**(0.26, 0.50)**	**<0.05**
Gentrifying	**0.43**	**(0.29, 0.57)**	**<0.05**
Model 2a: Effect modification by gentrification			
Active green space	**-0.82**	**(-1.59, -0.05)**	**<0.05**
Active green space X gentrification (Ref= Wealthy neighborhood)[a]			
Non-gentrifying	**1.23**	**(0.17, 2.29)**	**<0.05**
Gentrifying	-1.46	(-3.07, 0.15)	0.076
Model 2b: Effect modification by race/ethnicity			
Active green space	**-1.36**	**(-2.16, -0.56)**	**<0.05**
Active green space X race (Ref = NH White)[b]			
NH Black	1.54	(0.06, 3.02)	0.041
Hispanic	**1.07**	**(-0.07, 2.21)**	**0.066**
NH Asian	**-0.04**	**(-1.72, 1.63)**	**0.958**
NH Other	3.05	(-0.31, 6.40)	0.075
Model 2c: Effect modification by education			
Active green space	-0.27	(-0.85, 0.32)	0.373
Active green space X education (Ref <College degree)			
College degree or greater	**-1.68**	**(-2.72, -0.64)**	**<0.05**
Model 2d: Effect modification by income			
Active green space	-0.53	(-1.09, 0.03)	0.062
Active green space X poverty (Ref <400% or unknown)			
>=400% of poverty level	-0.65	(-1.82, 0.52)	0.274

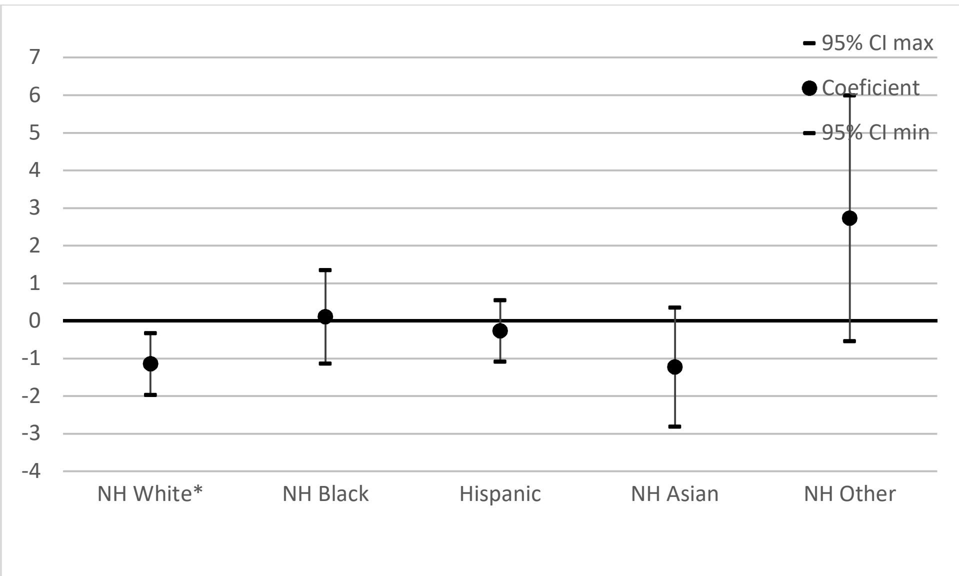
a. P-value from the Wald test of significance <0.05
b. P-value for the Wald test of significance 0.077

Figure 2: Regression coefficients for the relationship between percentage of active green space and reporting fair or poor health, stratified neighborhood gentrification status (2a), race/ethnicity (2b) and level of education (2c). All models are adjusted for individual-level and neighborhood-level co-variates. Strata where the relationship between active green space and health is significant at $p<0.05$ are indicated with a *.

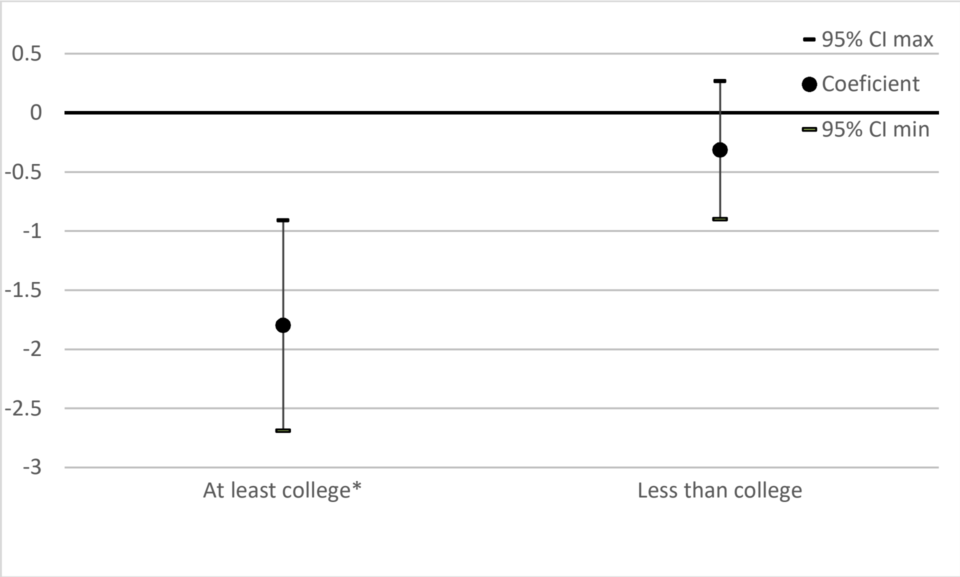
2a)



2b)



2c)



95% CI max
Coeficient
95% CI min
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
At least college*
Less than college

Figure 3: Predicted probability of reporting fair or poor health by quartiles of neighborhood active green space neighborhood gentrification status

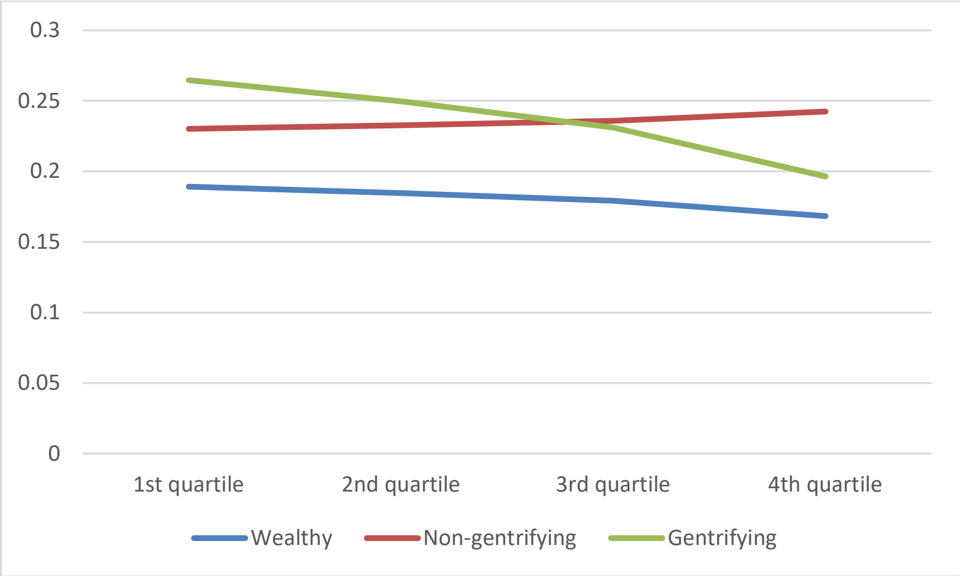


Table 3: Logistic regression coefficients for the relationship between percentage active green space in one's ZIP code and general self-rated health among residents of gentrifying neighborhoods.

	Coef	95% CI	p-value
Model 3: Green space and health in gentrifying neighborhoods			
Active green space	**-2.03**	**(-3.54, -0.52)**	**<0.05**
Model 3a: Effect modification by race in gentrifying neighborhoods			
Active green space	**-3.83**	**(-6.90, -0.76)**	**<0.05**
Active green space X race (Ref = NH White)[a]			
NH Black	2.65	(-1.79, 7.11)	0.244
Hispanic	1.82	(-1.79, 5.42)	0.323
NH Asian	3.26	(-3.99, 10.51)	0.378
NH Other	**14.18**	**(4.40, 23.96)**	**<0.05**
Model 3b: Effect modification by education in gentrifying neighborhoods			
Active green space	-1.69	(-3.22, 0.24)	0.091
Active green space X education (Ref <College degree)			
College degree or greater	-3.04	(-6.10, 0.03)	0.052
Model 3c: Effect modification by income in gentrifying neighborhoods			
Active green space	-1.34	(-2.97, 0.29)	0.106
Active green space X poverty (Ref <400% or unknown)			
>=400% of poverty level	**-4.91**	**(-9.29, -0.53)**	**<0.05**

a. P-value from the Wald test for significance 0.072

Figure 4: Logistic regression coefficients for the relationship between percentage of active green space and reporting fair or poor health, stratified samples by sociodemographic characteristic among residents of gentrifying neighborhoods. All models are adjusted for individual-level and neighborhood-level co-variates.