Neighborhood Greenness and Chronic Health Conditions in Medicare Beneficiaries

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Introduction: Prior studies suggest that exposure to the natural environment may impact health. The present study examines the association between objective measures of block-level greenness (vegetative presence) and chronic medical conditions, including cardiometabolic conditions, in a large population-based sample of Medicare beneficiaries in Miami-Dade County, Florida.

Methods: The sample included 249,405 Medicare beneficiaries aged ≥65 years whose location (ZIP+4) within Miami-Dade County, Florida, did not change, from 2010 to 2011. Data were obtained in 2013 and multilevel analyses conducted in 2014 to examine relationships between greenness, measured by mean Normalized Difference Vegetation Index from satellite imagery at the Census block level, and chronic health conditions in 2011, adjusting for neighborhood median household income, individual age, gender, race, and ethnicity.

Results: Higher greenness was significantly associated with better health, adjusting for covariates: An increase in mean block-level Normalized Difference Vegetation Index from 1 SD less to 1 SD more than the mean was associated with 49 fewer chronic conditions per 1,000 individuals, which is approximately similar to a reduction in age of the overall study population by 3 years. This same level of increase in mean Normalized Difference Vegetation Index was associated with a reduced risk of diabetes by 14%, hypertension by 13%, and hyperlipidemia by 10%. Planned post-hoc analyses revealed stronger and more consistently positive relationships between greenness and health in lower- than higher-income neighborhoods.

Conclusions: Greenness or vegetative presence may be effective in promoting health in older populations, particularly in poor neighborhoods, possibly due to increased time outdoors, physical activity, or stress mitigation.


Introduction

It has been suggested that a significant proportion of complex disease risk may be attributed to differences in individuals’ environmental exposures.1 One type of environmental exposure that has been linked to health outcomes is exposure to natural environments,2–13 including neighborhood greenness or vegetative presence.2,3,9–11,14–20 It has been hypothesized that higher levels of exposure to greenness may impact health through multiple mechanisms,2,3 including increased opportunities for physical activity,21,22 increased social interaction1,8,22 and social cohesion,2,3,22,23 restoration from mental fatigue,6,7 stress reduction,5,11,20 and reductions in air pollution,2,3,24 noise pollution,2,3 and heat/humidity.2,3,25

Recently, studies using a measure of neighborhood greenness or vegetative presence from satellite imagery, the Normalized Difference Vegetation Index (NDVI),26,27 have shown a relationship to lower BMI,14,15 lower risk of being overweight or obese,16,19 and possibly lower cardiovascular

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disease risk. Exposure to higher levels of greenness measured by NDVI has been linked to physical activity,
although this finding has not been universally obtained. Higher NDVI levels are also linked to less sedentary behavior. Higher NDVI has been linked to lower levels of perceived stress, but also was linked to lower social support in one study. Other studies have linked NDVI to mitigation of temperatures and air pollution. Future research is needed to better understand the relationship of objectively measured greenness (NDVI) to chronic health conditions, including intervening mechanisms.

The present study examines the relationship between greenness (NDVI) and objectively measured chronic conditions in a population-based sample of U.S. Medicare beneficiaries aged 65 years and older, who may be at high risk for obesity-related chronic conditions. This is the first study to examine the relationship of greenness measured by mean NDVI at the block level to residents’ health outcomes, and is motivated by research findings suggesting that “microenvironmental” conditions at the block level may be related to health outcomes in older adults and other vulnerable populations (low-income, minorities, children), who may be disproportionately influenced by their immediate residential environment. Given the well-established role of neighborhood socioeconomic conditions in health outcomes, this study also explores whether the relationship between mean block-level greenness (NDVI) and individuals’ health is moderated by neighborhood income level.

Methods

Study Design

The present study compared chronic health conditions among a population-based sample of Medicare beneficiaries aged ≥65 years in Miami-Dade County, Florida, whose location did not change from 2010 to 2011 (Figure 1), in relation to the level of greenness (mean NDVI) for each resident’s Census block. This comparison was further analyzed in relation to neighborhood income levels.

Data

Data were obtained for this retrospective cohort study in 2013 from the U.S. Centers for Medicare and Medicaid Services (CMS)’ Master Beneficiary Summary File, which provided for each beneficiary, annual data on health outcomes, age, gender, race/ethnicity, and location, for the calendar years 2010–2011. The CMS Master Beneficiary Summary File Chronic Conditions Segment provides indications of 27 chronic conditions, using CMS’ chronic conditions algorithms, based on Medicare claims of all types for each beneficiary in a calendar year. The present study assessed total illness burden based on the total number of chronic conditions (out of a range of 0–27 chronic conditions) available for CMS for each beneficiary. In addition, with nearly 60% overweight/obesity-related illness burden in Miami-Dade County, further analyses focused on a possible range of 0–12 obesity-related chronic conditions found in a systematic literature review (Appendix A, available online) to be causally related to obesity, and identified three leading cardiometabolic risk factors hypothesized to be related to the built environment, including greenness—diabetes, hypertension, and hyperlipidemia—for separate individual analyses.

U.S. National Aeronautics and Space Administration Advanced Spaceborne Thermal Emission and Reflection Radiometer satellite imagery at a 15 × 15-meter spatial resolution was used to calculate greenness or vegetative presence by NDVI, with continuous measurements that ranged from −1 to +1, with higher values indicating more greenness. Mean NDVI was derived for all Miami-Dade County Census blocks for 2011 (Figure 2; Appendix B, available online). All analyses assessed NDVI to health relationships using a 0.1-unit change in NDVI, given prior work suggesting that this corresponds to meaningful/discriminable land changes in urban and suburban environments, which characterize the areas where most of Miami-Dade County reside.

U.S. Census Bureau 2011 data provided neighborhood median household income at the Census block group level. Neighborhood median household income was used as a stratification variable with three levels: low-income (≤$31,600, the lowest 25th percentile in which Medicare beneficiaries resided), middle-income (≥$25th to ≤75th percentile), and high-income (≥$62,400, ≥75th percentile).

The final study sample (Figure 1) was derived in stages. Beginning with the 2011 CMS Master Beneficiary Summary File for Miami-Dade County of 407,296 unique Medicare beneficiaries, the following exclusions were made: First, those beneficiaries were excluded who lived outside of Miami-Dade County (n=11,507). Beneficiaries who died were excluded (n=14,296), as were those with end-stage renal disease (n=3,572), and those aged <65 years or born before 1900 (n=64,109). Further exclusions included those beneficiaries who could not be matched to a specific ZIP code location associated with a Census block (n=14,401) and members of an ethnic/racial group (Asian, Pacific Islander, Native American) representing <1% of the Miami-Dade County senior population (n=12,132). Finally, beneficiaries were excluded who did not retain the same location in 2010–2011 (n=34,584), as well as those with nursing home claims, who may have been in a nursing home for all or part of the calendar year, in which case their location may have corresponded to a billing address rather than an actual residence (n=3,630). This resulted in a final cohort of 249,405 Medicare beneficiaries aged ≥65 years who had the same location (based on ZIP code + 4-digit locator) across 2 calendar years (2010–2011). ZIP+4 data from CMS data were linked to a Census block for each beneficiary using Geolytics ZIP+4 software, which provides the area centroid of the ZIP+4 with latitude and longitude coordinates, and assigns the corresponding 2010 Census block, block group, and tract identification numbers. This study was approved by the University of Miami’s IRB and CMS’ Privacy Board.

Statistical Analysis

Descriptive and multilevel analyses were conducted in 2014 using SAS, version 9.3. For the main analyses, a three-level framework was utilized in which neighborhood median household income at the 2011 U.S. Census Bureau block group level (the smallest
geographic scale at which this variable is available) was treated as a Level 3 variable in the model, and greenness, measured at the Census block level (hereafter, the block level) by mean NDVI, for all 36,563 Census blocks in the County, as a Level 2 variable. Individual-level variables of age, gender, race, and ethnicity were treated as Level 1 variables in the model.

For each health outcome, PROC GLIMMIX was used to model the relationship of NDVI to health in a multilevel framework, adjusting for covariates. For the five dichotomous outcomes, presence or absence of diabetes, hypertension, and hyperlipidemia, and the presence or absence of any chronic conditions or obesity-related chronic conditions, PROC GLIMMIX was used with a binary response distribution, which handles multilevel regression for binary variables.

For the two remaining outcomes, which examined both the total number of chronic conditions and the number of obesity-related conditions, PROC GLIMMIX was selected with a Poisson response distribution, as the most appropriate type of modeling for use with count variables. Finally, analyses examined whether the relationship between NDVI and each health outcome varied by neighborhood income level, in which neighborhood income level was entered as an interactive term (multiplied by NDVI) while retaining neighborhood income as a covariate in the analyses.

Table 1 illustrates descriptive statistics for the sample. Demographic characteristics for the study sample closely resemble those of all adults aged ≥65 years residing in Miami-Dade County— which the 2013 U.S. Census estimates as 58% female, 68% Hispanic, 19% non-Hispanic white, and 13% black, for all adults aged ≥65 years in the county. NDVI levels were higher on average in higher-income neighborhoods than in medium- and lower-income neighborhoods, although a relatively wide range of NDVI levels was evident across all neighborhood income levels. Residents of lower-income neighborhoods were significantly more

Figure 1. Flow diagram indicating data processing steps for deriving the final cohort of 249,405 Medicare beneficiaries aged 65 and older with the same location in Miami-Dade County, Florida, in 2010—2011. MDC, Miami Dade County; NDVI, Normalized Difference Vegetation Index.
likely to be female, older, a racial/ethnic minority (Hispanic or black), and with more chronic conditions on average, when compared with residents of medium- or high-income neighborhoods.

**Results**

Higher levels of greenness as measured by mean NDVI were associated with a notable reduction in chronic conditions. Each 0.1-unit increase in NDVI was significantly associated with a 7% greater likelihood of being free of any chronic condition for the overall sample, and 28 fewer chronic conditions per 1,000 individuals among those beneficiaries having one or more chronic conditions. Each 0.1-unit increase in NDVI was associated with an 8% greater likelihood of being free of obesity-related chronic conditions, and 30 fewer obesity-related conditions per 1,000 individuals among beneficiaries having one or more chronic conditions. Further, each 0.1-unit increase in NDVI is associated with a significantly reduced risk of three specific chronic conditions: diabetes (8%), hypertension (7%), and hyperlipidemia (6%). Table 2 presents the main analyses on the relationship of greenness with each health outcome for the overall sample.

Additional analyses determined that an increase in NDVI from 1 SD less to 1 SD more than mean for this sample was associated with a reduced risk of 14% for diabetes, 13% for hypertension, and 10% for hyperlipidemia, as well as 49 fewer chronic conditions per 1,000 individuals, and a 13% greater likelihood of freedom from chronic conditions. An increase of 49 chronic
Table 1. Descriptive Statistics for the Overall Sample, and by Neighborhood Income Level

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall sample (all neighborhood income levels)</th>
<th>Low-income neighborhoods (lowest quartile on income)</th>
<th>Medium-income neighborhoods (middle 50% on income)</th>
<th>High-income neighborhoods (highest quartile on income)</th>
<th>( F(\chi^2) ) test</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beneficiaries, n (%)</td>
<td>249,405 (100.0)</td>
<td>62,383 (25.01)</td>
<td>124,898 (50.08)</td>
<td>62,124 (24.91)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Neighborhood median household income</td>
<td>—</td>
<td>51.4 (30.7)</td>
<td>23.0 (6.0)</td>
<td>45.3 (8.9)</td>
<td>92.4 (31.9)</td>
<td>263,465</td>
</tr>
<tr>
<td>Main predictor: NDVI</td>
<td>—</td>
<td>-0.02 (0.09)</td>
<td>-0.06 (0.08)</td>
<td>-0.03 (0.08)</td>
<td>0.03 (0.10)</td>
<td>17,425.4</td>
</tr>
<tr>
<td>Individual demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>—</td>
<td>76.33 (7.50)</td>
<td>76.79 (7.51)</td>
<td>76.34 (7.48)</td>
<td>75.85 (7.50)</td>
<td>244.6</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>58.33</td>
<td>59.07</td>
<td>58.88</td>
<td>56.48</td>
<td></td>
<td>(116.8)</td>
</tr>
<tr>
<td>Race/ethnicity (RTI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(21,647)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>65.56</td>
<td>73.74</td>
<td>68.48</td>
<td>51.48</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>23.29</td>
<td>9.78</td>
<td>20.27</td>
<td>42.92</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>Black</td>
<td>11.15</td>
<td>16.48</td>
<td>11.26</td>
<td>5.60</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>Outcome variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of total chronic conditions (0–27)</td>
<td>—</td>
<td>2.05 (3.22)</td>
<td>2.44 (3.58)</td>
<td>1.86 (3.12)</td>
<td>2.06 (2.98)</td>
<td>674.2</td>
</tr>
<tr>
<td>No. of obesity-related conditions (0–12)</td>
<td>—</td>
<td>1.06 (1.69)</td>
<td>1.28 (1.88)</td>
<td>0.96 (1.64)</td>
<td>1.03 (1.57)</td>
<td>756.4</td>
</tr>
<tr>
<td>Diabetes diagnosis</td>
<td>15.55</td>
<td>19.67</td>
<td>14.09</td>
<td>14.35</td>
<td></td>
<td>(1,076)</td>
</tr>
</tbody>
</table>

(continued on next page)
### Table 1. Descriptive Statistics for the Overall Sample, and by Neighborhood Income Level (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall sample (all neighborhood income levels)</th>
<th>Low-income neighborhoods (lowest quartile on income)</th>
<th>Medium-income neighborhoods (middle 50% on income)</th>
<th>High-income neighborhoods (highest quartile on income)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% (SD) Range</td>
<td>% (SD) Range</td>
<td>% (SD) Range</td>
<td>% (SD) Range</td>
</tr>
<tr>
<td>Hypertension diagnosis</td>
<td>27.88 — —</td>
<td>31.66 — —</td>
<td>25.41 — —</td>
<td>39.06 — —</td>
</tr>
<tr>
<td>Hyperlipidemia diagnosis</td>
<td>22.72 — —</td>
<td>23.86 — —</td>
<td>20.50 — —</td>
<td>26.04 — —</td>
</tr>
</tbody>
</table>

Note: Boldface indicates statistical significance (p < 0.0001).

4 Neighborhood median household income is reported in thousands of dollars, at the Census block group level, using 2011 U.S. Census Bureau data. For stratification purposes, this variable was used to categorize neighborhoods as low, medium, or high neighborhood median household income (i.e., based on the lowest quartile, middle 50%, and top quartile of this variable, respectively).

5 NDVI was calculated to assess greenness/vegetative presence/absence at the Census block level, with a possible theoretical range of −1 to +1 (Appendix B, available online).

6 Race and ethnicity was assessed by CMS for each beneficiary using the RTI race code, an enhanced race/ethnicity designation for Medicare using first/last name algorithms.

7 Total chronic conditions were calculated based on the total number of chronic conditions (out of a possible 27 chronic conditions) for which the Medicare beneficiary met CMS’ chronic condition algorithm criteria in 2011 (using the 2011 CMS Master Beneficiary Summary File, Chronic Conditions Segment; Appendix A, available online).

8 Number of obesity-related chronic conditions was calculated (out of a possible range of 0–12) for each beneficiary in 2011, based on a systematic literature review that identified epidemiologic evidence that obesity was moderately to strongly causally related to 12 of CMS’ 27 chronic conditions in the Master Beneficiary Summary File, Chronic Conditions Segment (Appendix A, available online).

9 Diagnoses of diabetes, hypertension, and hyperlipidemia were identified for each Medicare beneficiary for the calendar year 2011, using the 2011 CMS Master Beneficiary Summary File, Chronic Conditions Segment.

CMS, Centers for Medicare and Medicaid Services; NDVI, Normalized Difference Vegetation Index; RTI, Research Triangle Institute.
Table 2. NDVI Relationships to Health Outcomes for Overall Sample, and by Neighborhood Income Level

<table>
<thead>
<tr>
<th>Health Outcome</th>
<th>Overall sample (all neighborhood income levels)</th>
<th>Low-income neighborhoods (lowest quartile on income)</th>
<th>Medium-income neighborhoods (middle 50% on income)</th>
<th>High-income neighborhoods (highest quartile on income)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 249,405)</td>
<td>(n = 62,383)</td>
<td>(n = 124,898)</td>
<td>(n = 62,124)</td>
</tr>
<tr>
<td>F-test of NDVI\times neighborhood income interaction</td>
<td>Estimate SE</td>
<td>p-value</td>
<td>Estimate SE</td>
<td>p-value</td>
</tr>
<tr>
<td>No. of chronic conditions (binary logit model and Poisson model)</td>
<td>0.0665 0.0089</td>
<td>0.0001 0.777</td>
<td>0.0698 0.0099</td>
<td>0.0001 0.802</td>
</tr>
<tr>
<td>Total no. of chronic conditions</td>
<td>0.1545 0.0178</td>
<td>0.0001 0.727</td>
<td>0.1567 0.0177</td>
<td>0.0001 0.802</td>
</tr>
<tr>
<td>Whether have zero chronic conditions</td>
<td>0.0393 0.0123</td>
<td>0.0001 0.004</td>
<td>0.040 0.0123</td>
<td>0.0001 0.004</td>
</tr>
<tr>
<td>No. of obesity-related conditions</td>
<td>0.0694 0.0141</td>
<td>0.0001 0.777</td>
<td>0.073 0.0141</td>
<td>0.0001 0.777</td>
</tr>
<tr>
<td>Whether have zero obesity-related conditions</td>
<td>0.094 0.0156</td>
<td>0.0001 0.777</td>
<td>0.100 0.0156</td>
<td>0.0001 0.777</td>
</tr>
<tr>
<td>No. of obesity-related conditions</td>
<td>0.0306 0.0032</td>
<td>0.0001 0.004</td>
<td>0.030 0.0032</td>
<td>0.0001 0.004</td>
</tr>
<tr>
<td>Whether have zero obesity-related conditions</td>
<td>0.053 0.0123</td>
<td>0.0001 0.004</td>
<td>0.053 0.0123</td>
<td>0.0001 0.004</td>
</tr>
<tr>
<td>Individual diagnoses (binary logit models)</td>
<td>0.0855 0.0102</td>
<td>0.0001 0.449</td>
<td>0.084 0.0102</td>
<td>0.0001 0.449</td>
</tr>
<tr>
<td>Diabetes diagnosis</td>
<td>0.1453 0.0194</td>
<td>0.0001 0.273</td>
<td>0.147 0.0194</td>
<td>0.0001 0.273</td>
</tr>
<tr>
<td>Whether have diabetes diagnosis</td>
<td>0.053 0.0148</td>
<td>0.0001 0.004</td>
<td>0.053 0.0148</td>
<td>0.0001 0.004</td>
</tr>
<tr>
<td>No. of obesity-related conditions</td>
<td>0.094 0.0160</td>
<td>0.0001 0.777</td>
<td>0.100 0.0160</td>
<td>0.0001 0.777</td>
</tr>
<tr>
<td>Whether have zero obesity-related conditions</td>
<td>0.053 0.0174</td>
<td>0.0001 0.004</td>
<td>0.053 0.0174</td>
<td>0.0001 0.004</td>
</tr>
</tbody>
</table>

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Table 2. NDVI Relationships to Health Outcomes for Overall Sample, and by Neighborhood Income Level (continued)

<table>
<thead>
<tr>
<th>Health outcome variables (models)</th>
<th>Overall sample (all neighborhood income levels) (n=249,405)</th>
<th>Low-income neighborhoods (lowest quartile on income) (n=62,383)</th>
<th>Medium-income neighborhoods (middle 50% on income) (n=124,898)</th>
<th>High-income neighborhoods (highest quartile on income) (n=62,124)</th>
<th>F-test of NDVI x neighborhood income interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
<td>p-value</td>
<td>OR or Δ prevalence (95% CI)</td>
<td>Estimate</td>
</tr>
<tr>
<td>Hypertension diagnosis</td>
<td>-0.0760</td>
<td>0.0090</td>
<td>&lt;0.0001*</td>
<td>0.927 (0.911, 0.943)</td>
<td>-0.1466</td>
</tr>
<tr>
<td>Hyperlipidemia diagnosis</td>
<td>-0.0603</td>
<td>0.0096</td>
<td>&lt;0.0001*</td>
<td>0.941 (0.924, 0.959)</td>
<td>-0.1185</td>
</tr>
</tbody>
</table>

Note: Boldface indicates statistical significance (* p < 0.0001; ** p < 0.01; *** p < 0.05; **** p < 0.001).

*Neighborhood median household income is at the Census block group level, using 2011 U.S. Census Bureau data. For stratification purposes, this variable was used to categorize neighborhoods as low, medium, or high neighborhood median household income (i.e., based on the lowest quartile, middle 50%, and top quartile of this variable, respectively).15

1NDVI was calculated to assess greenness/vegetative presence/absence at the Census block level, with a possible theoretical range of –1 to +1. Coefficients are reported for a 0.1-unit increase in NDVI, given that a 0.1-unit change in NDVI indicates measurable/discernible changes in greenness in urban and peri-urban settings (Appendix B, available online).15

1Total chronic conditions was calculated based on the total number of chronic conditions (out of a possible 27 chronic conditions) for which the Medicare beneficiary met CMS’ chronic condition algorithm criteria in 2011 (using the 2011 CMS Master Beneficiary Summary File, Chronic Conditions Segment; Appendix A, available online).35

Number of obesity-related chronic conditions was calculated (out of a possible range of 0-12) for each beneficiary in 2011, based on a systematic literature review that identified epidemiologic evidence that obesity was moderately to strongly causally related to 12 of CMS’ 27 chronic conditions in the Master Beneficiary Summary File, Chronic Conditions Segment.35

Diagnoses of diabetes, hypertension, and hyperlipidemia, respectively, were identified for each Medicare beneficiary for 2011, using the 2011 CMS Master Beneficiary Summary File, Chronic Conditions Segment.35

CMS, Centers for Medicare and Medicaid Services; NDVI, Normalized Difference Vegetation Index; Δ prevalence, change in number of conditions per 1,000 individuals.
conditions per 1,000 individuals from 1 SD above to below the mean on NDVI is approximately similar to a biomedical aging of the present sample by 3 years.

Further analyses examined whether neighborhood income level moderated the relationship of greenness with each health outcome (Table 2). For most health outcomes, there was a significant cross-level interaction between neighborhood median household income and greenness, such that higher levels of NDVI were associated with significantly higher and more consistently beneficial improvements in health outcomes for residents of low- and medium-income neighborhoods, compared with high-income neighborhoods.

Each 0.1-unit increase in NDVI was associated with a significantly greater likelihood of being free of chronic conditions for residents of low- (OR=1.167, p < 0.0001) and medium-income neighborhoods (OR=1.040, p=0.0014), and a lesser likelihood for residents of high-income neighborhoods (OR=0.914, p < 0.0001). Similarly, a 0.1-unit increase in NDVI was associated with a greater likelihood of being free of obesity-related chronic conditions for residents of low- (OR=1.168, p < 0.0001) and medium-income neighborhoods (OR=1.049, p < 0.0001), and a lesser likelihood for residents of high-income neighborhoods (OR=0.939, p < 0.0001).

There was a significant cross-level interaction between neighborhood income level and NDVI in predicting risk of diabetes, hypertension, and hyperlipidemia. Higher NDVI levels were associated with reduced diabetes risk for residents of low- (OR=0.865, p < 0.0001) and medium-income neighborhoods (OR=0.952, p=0.0006), but not residents of high-income neighborhoods (OR=0.993, p=0.68); reduced hypertension risk for residents of low- and medium-income neighborhoods (OR=0.864 and 0.953, p ≤ 0.0001, respectively) and increased hypertension risk for residents of high-income neighborhoods (OR=1.046, p=0.0013); and reduced risk of hyperlipidemia for residents of low- (OR=0.888, p < 0.0001) and medium-income neighborhoods (OR=0.972, p=0.0337) and greater risk for residents of high-income neighborhoods (OR=1.044, p=0.0032). Neighborhood income level did not interact with NDVI in relation to either the total number of chronic conditions or the number of obesity-related chronic conditions (Table 2).

Discussion

Higher levels of greenness (measured by mean NDVI at the Census block level) were associated with fewer total chronic conditions and lower rates of cardiometabolic conditions—diabetes, hypertension, and hyperlipidemia—in this sample. This study builds upon previous findings that higher levels of neighborhood greenness, measured by mean NDVI, are associated with lower BMI,14,15 lower risk of being overweight or obese,16,19 and possibly reduced cardiovascular disease risk.17

At a population level, relatively small changes in mean NDVI at the Census block level (in this case, a 0.178-unit change in NDVI corresponds to a change from 1 SD below the mean to above the mean) may be associated with notable reductions in cardiometabolic risk factors and in the total number of chronic conditions. Although the present results are correlational in nature, these findings suggest that added greenness or vegetative presence could beneficially impact total and obesity-related illness burden. In a warm climate such as south Florida, it is possible that the presence of greenness or vegetation, including possibly more street trees and shade-enhanced neighborhoods, may enhance the possibility for greater time outdoors or physical and social activity,19,28,50,39 or alternatively may reduce stress because of the hypothesized restorative effects of exposure to nature.6,7

Additionally, the relationships between block-level greenness and health outcomes were moderated by neighborhood income level, such that, for most health outcomes, greenness evidenced significantly stronger and more consistently beneficial relationships with health for residents of lower- and middle-income neighborhoods than residents of higher-income neighborhoods. It may have been the case that the benefits of increasing greenness in lower-income neighborhoods were proportionately greater than in higher-income neighborhoods for most health outcomes, because in higher-income neighborhoods, the average level of greenness is already significantly higher than in low- and medium-income neighborhoods (Table 1). Interestingly, when examining effect modification by race/ethnicity for greenness’ relationship with each cardiometabolic condition, higher greenness was consistently and positively associated with better health outcomes in low-income neighborhoods (a median household income ≤ $31,600) for all three racial/ethnic groups in this study (Hispanics, blacks, and non-Hispanic whites). However, in middle-income neighborhoods, only Hispanics (66% of the sample) showed consistently positive associations of greenness with health. No racial/ethnic group showed consistently beneficial relationships between greenness and health in higher-income neighborhoods (≥ $62,400). These relationships require further study to better understand under what circumstances, and for whom, greenness is related to health.

Although not measured in this study, physical activity may be a factor in the findings of increased hypertension and hyperlipidemia risk in higher-income neighborhoods with higher NDVI. Generally, these locations are suburban neighborhoods and subject to sprawl effects.
because there are few amenities, such as shops and restaurants, located within walking distance of homes. In such cases, reduced overall physical activity levels may account for the higher levels of hypertension and hyperlipidemia observed for individuals in this sample, residing on greener blocks in high-income neighborhoods. This finding, however, requires further study.

With a strong, objective data set in a highly powered population-based study, and a research-founded hypothesis that greenness or vegetative presence would be associated with better outcomes, this is the first study to show that higher levels of block-level greenness (mean NDVI) are associated with better health outcomes in a large population-based sample of older adults. More specifically, higher mean NDVI is associated with fewer chronic conditions and fewer obesity-related conditions, measured objectively. Additionally, this is the first study to identify a significant relationship of greenness with diabetes, hypertension, and hyperlipidemia. Few prior studies have identified the relationship of the neighborhood built and natural environment with these cardiometabolic risk factors, which have been increasing in recent years, and may be impacted by changes in land use, such as destinations for walking or recreation and greenness.37,38

Limitations

There are limitations. The present study focused on a particular, large county, so it is yet to be determined if these findings are generalizable to a different climate zone and population. Medicare data did not provide the beneficiaries’ history of moves or reasons for selecting their current location, although the sample was restricted to individuals who had the same location for 2 calendar years. The cross-sectional nature of the present study limits assertions about causality, as does the lack of information about environmental exposures beyond the residential block.

Residential self-selection, that is, the choice of one’s residence on the basis of physical or social characteristics, is a known issue in the built environment and health literature,42 and it is possible that healthier individuals, or those who prefer physical activity or access to nature, may have selected greener environments. However, the present finding that greenness is generally more strongly related to health outcomes in lower-income neighborhoods speaks against an explanation based solely on residential self-selection, as lower-income individuals may have fewer neighborhood choices,43 and yet generally showed a stronger and more consistently beneficial relationship of greenness with health outcomes than did residents of higher-income neighborhoods.

Specific mechanisms through which greenness may impact on health such as increased physical activity and social interactions or restoration6,44 were not available, nor were other mediating or moderating factors, such as perceived safety or aesthetics. Other unmeasured mechanisms, such as lower exposure to air pollution, decreased exposure to extreme temperatures, and potentially buffered noise exposure, may account for the greenness to health relationships found in this study.27,3

Information was lacking on potential individual-level confounders, such as smoking and individual SES. Finally, NDVI does not reveal specific types of greenery or vegetation.76 Longitudinal studies that examine specific types of vegetation, across changes in residence, including reasons for moves, and in relation to residents’ health outcomes over time can provide a clearer picture of these relationships.

Conclusions

Higher levels of block-level greenness (mean NDVI) are associated with reductions in the number of chronic conditions and in the prevalence of cardiometabolic conditions. These relationships between greenness and health outcomes were found in a population-based sample of 249,405 Medicare beneficiaries aged 65 years and older, who have access to a relatively similar level of health care through the U.S. Medicare system. They represent a large and growing population at risk for chronic health conditions and healthcare utilization over time.29 Moreover, the greenness—health relationship was stronger for lower- than higher-income neighborhoods. Prior work suggests that exposure to nature,12,13,45 as well as possibly increased opportunities for walking, socializing, or stress reduction—which may occur through increased greenness or vegetation—may be important for maintaining senior populations’ health.22,30,46–48 This study suggests that increasing greenness or vegetation in a neighborhood may potentially be a useful strategy to reduce disease burdens at the population level and enhance residents’ quality of life.

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References


Appendix

Supplementary data

Supplementary data associated with this article can be found at http://dx.doi.org/10.1016/j.amepre.2016.02.008.