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Association Between Access to Social Service Resources and Cardiometabolic Risk Factors: A Machine Learning and Multi-Level Modeling Analysis

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3 **Association Between Access to Social Service Resources and Cardiometabolic**
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5 **Risk Factors: A Machine Learning and Multi-Level Modeling Analysis**
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3 **Objectives:** Interest in linking patients with unmet social needs to area-level
4 resources, such as food pantries and employment centers, is growing. However,
5
6 whether the presence of these resources is associated with better health outcomes
7
8 is unclear. We sought to determine if area-level resources are associated with lower
9
10 levels of cardiometabolic risk factors.
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15 **Design:** Cross-sectional.
16

17 **Setting:** Data were collected in a primary care network in eastern Massachusetts in
18
19 2015.
20

21
22 **Participants and Primary and Secondary Outcome Measures:** 123,355
23 participants were included. The primary outcome was body mass index (BMI). The
24 secondary outcomes were systolic blood pressure (SBP), low density lipoprotein
25 cholesterol (LDL), and hemoglobin a1c (HbA1c). All participants were included in
26 BMI analyses. Participants with hypertension were included in SBP analyses.
27
28 Participants with an indication for cholesterol lowering were included in LDL
29 analyses, and participants with diabetes mellitus were included in HbA1c analyses.
30
31 We used a random forest-based machine-learning algorithm to identify types of
32 resources associated with study outcomes. We then tested the association of
33
34 selected resources with these outcomes, using multi-level models to account for
35
36 individual-level, clinic-level, and other area-level factors.
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41 **Results:** Resources associated with lower BMI included more food resources (-0.08
42
43 kg/m² per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m²),
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45 employment resources (-0.05 kg/m², 95%CI -0.11 to -0.002 kg/m²), and nutrition
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3 resources (-0.07 kg/m², 95%CI -0.13 to -0.01 kg/m²). No area resources were
4
5 associated with differences in SBP, LDL, or HbA1c.
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8 **Conclusions:** Access to specific local resources is associated with better BMI. Efforts
9
10 to link patients to area resources, and to improve the resources landscape within
11
12 communities, may help reduce BMI and improve population health.
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Strengths and Limitations of the Study

- Strengths: Extensive individual and area-level data and
- Strengths: Innovative machine learning methods to overcome issues of collinearity and avoid multiple testing
- Strengths: Use of falsification tests
- Strengths: Use hierarchical linear modeling to account for data structure
- Limitations: Cross-sectional study

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2
3 Cardiometabolic disease remains the most common cause of morbidity and
4 mortality in the U.S.¹ Though better control of cardiometabolic risk factors could
5 substantially reduce this morbidity and mortality, individuals with low
6 socioeconomic status (SES) are less likely to achieve recommended goals.² Among
7 the reasons for this are unmet basic needs, including such factors as food insecurity,
8 housing instability, and lack of transportation. These unmet needs have been
9 associated with higher levels of important cardiometabolic risk factors including
10 increased body mass index (BMI), systolic blood pressure (SBP), low density
11 lipoprotein cholesterol (LDL), and hemoglobin A1c (HbA1c), even after adjusting for
12 factors like race/ethnicity, income, and education.³⁻⁸
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29 Healthcare systems are increasingly interested in working with community partners
30 to help link their patients to local resources, such as food pantries or housing
31 agencies, to help meet these social needs.⁹⁻¹³ This approach is exemplified by the
32 Accountable Health Communities initiative from the Centers for Medicare &
33 Medicaid Services, which involves screening for adverse social circumstances and
34 linking those who screen positive to community resources.¹⁴ However, there remain
35 significant gaps in knowledge regarding such approaches. Critically, healthcare
36 systems need to know which organizations to partner with, and potentially what
37 types of resources to invest in.¹⁵ This is especially true as the connection between
38 resource type and need may not always be straightforward. For example, a food
39 pantry could help alleviate food insecurity, but so could employment. Further, the
40 relationship between specific health conditions and area-resources needs further
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3 study. Aspects of some conditions, such as HbA1c in those with diabetes mellitus,
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5 may be more amenable to intensive clinical management. Others, such as BMI, may
6
7 have less effective treatment options within the healthcare system. Therefore, the
8
9 role that area resources play may differ depending on the intensity and impact of
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11 concurrent clinical management. This distinction is important both for population
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13 health, and for healthcare systems trying to decide where to invest in order meet
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15 population health metrics that cannot easily be achieved through clinical care alone.
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22 To help address these issues, and inform further interventions, we sought to study
23
24 associations between area-resources and cardiometabolic risk factors in a large
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26 primary care network. Our goal was to understand which resource types were
27
28 associated with improved levels of BMI, SBP, LDL, and HbA1c, and to determine
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30 whether area-resources had stronger associations with cardiometabolic risk factors
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32 for conditions that are less amenable to clinical management.
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38 **Methods**

39 *Setting and Study Sample*

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41 Data for this study came from two primary sources: an asset mapping of community
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43 resources, and electronic health records. The asset mapping came from the
44
45 HelpSteps database, a comprehensive asset mapping of area-resources in eastern
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47 Massachusetts maintained by the Mayor's Health Line at the Boston Public Health
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49 Commission and Boston Children's Hospital.¹⁶ The clinical records came from a
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51 primary care network in eastern Massachusetts, a network of 18 primary care
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3 practices, including hospital-based, academic, and community health center sites. All
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5 adult (age ≥ 18 years) primary care patients seen between January 1, 2012 and
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7 December 31, 2015 were included. Data were current on December 31, 2015. The
8
9 most recent patient address was geocoded for the study. Patients without available
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11 addresses were excluded—prior work has shown that only 0.15% of patients in this
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13 cohort could not be geocoded.¹⁷
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19 The Partners Healthcare Human Research Committee exempted this analysis of
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21 secondary data without patient contact from IRB review.
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24 25 26 *Patient and Public Involvement*

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28 The study research question was developed in reference to patient priorities
29
30 regarding the incorporation of neighborhood factors that promote health into
31
32 population health management. Patients were not involved in the design of the
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34 study or in recruitment. We plan to disseminate study results via open-access
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36 publication.
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43 44 *Area Resources*

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46 The HelpSteps database contains information on area-resources across 16 non-
47
48 mutually exclusive domains: health, housing, food (e.g. food pantries), employment,
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50 violence, safety, substance abuse, mental health, education, parenting, nutrition (e.g.
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52 nutrition counseling), after school, sexual health, transportation, diabetes, and care
53
54 transitions. Agencies providing multiple resources could be included in more than
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3 one domain. Area-resources were also geocoded, and then counts of resources for
4 each domain were calculated at 4 geographic levels in roughly increasing order of
5 size: census tract (using U.S. Census 2010 boundaries), ZIP code tabulation area
6 (which we refer to throughout this paper as 'ZIP' level, owing to common use of the
7 term, again using U.S. Census 2010 boundaries), 'neighborhood' (e.g. Allston,
8 Roxbury, a designation based on Boston city planning that may better capture actual
9 movement patterns), and county.
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22 *Clinical Outcomes*

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24 To assess clinical outcomes, we calculated the mean of all values recorded in 2015
25 from individual's electronic health record for the following measurements: body
26 mass index (in kg/m²), systolic blood pressure (in mm Hg), low-density lipoprotein
27 cholesterol (in mg/dL) and HbA1c (%). All values were obtained in the process of
28 usual care.
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38 *Covariates*

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40 To account for possible confounding of the association between area resources and
41 health outcomes, we collected the following variables from the electronic health
42 record: age (years), gender (male or female), race/ethnicity (non-Hispanic white,
43 non-Hispanic black, Hispanic, or Asian/other/multi), education (less than high
44 school diploma, high school diploma [including GED], or greater than high school
45 diploma), insurance (commercial, Medicare, Medicaid [including dual-eligibles], and
46 uninsured/self-pay), number of clinic visits in 2015, primary language (English vs.
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3 other), connectedness to their primary care clinic using previously validated
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5 algorithm¹⁸, and comorbidity (Charlson comorbidity score, and individual indicators
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7 of depression, hypertension, coronary heart disease, osteoarthritis, and diabetes).
8
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10 To account for area-level differences from factors other than resources, we used
11
12 data from the U.S. Census' American Community Survey (5-year estimates 2010-
13
14 2015) and the USDA's Food Access Research Atlas: median household income,
15
16 percent living in poverty, 'food desert' status [low-income, low food access census
17
18 tract at 1/2 mile in urban areas and 10 miles in rural areas], unemployment rate,
19
20 proportion of the area population living in group quarters (e.g., those living in a
21
22 nursing facility unlikely to be exposed to area-level conditions), vehicle access, and
23
24 housing segregation.^{19,20}
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31 *Statistical analysis*

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33 In this study, we wanted to evaluate the relationship between many resources types
34
35 and cardiometabolic risk factors. A secondary goal of our study was to help
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37 understand the relationship that specific geographic levels and resource types had
38
39 with clinical outcomes. To avoid multiple hypothesis testing that may lead to the
40
41 identification of spurious associations, we employed a machine learning technique
42
43 called variable selecting using random forest (VSURF) to screen through variables in
44
45 the derivation set.^{21,22} This was done using a derivation dataset, which consisted of a
46
47 random partition of the entire dataset. Finally, we used multi-level modeling in the
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49 test set (not used in the derivation stage) to test a small number of candidate
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51 variables identified by VSURF as being most important to explaining variations in
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3 the derivation set. VSRUF is described in more detail in the technical appendix and
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5 eFigure 1.
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10 Multi-level modeling

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12 In the test dataset, we fit multi-level linear mixed models to test the association
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14 between variables identified in the VSURF step and the outcome of interest. The BMI
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16 model included all study participants. The SBP model included those with a
17
18 diagnosis of hypertension. The LDL model included those with common diagnoses
19
20 (hypertension, diabetes, coronary heart disease, cerebrovascular disease, congestive
21
22 heart failure) where LDL lowering is most beneficial. The HbA1c models included
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24 those with a diagnosis of diabetes. The models used fixed effects to adjust for age,
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26 gender, race/ethnicity, education, insurance, number of clinic visits, language, clinic
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28 connectedness, comorbidity, and census tract level median household income,
29
30 poverty rates, 'food desert' status, unemployment, numbers living in group quarters,
31
32 vehicle access, and segregation. To account for clustering within practices, we
33
34 included a practice-level random effects term. To account for area-level clustering,
35
36 we used a ZIP-level random effects term. These were fit as crossed effects models
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38 (i.e., we did not nest practices within ZIP codes) to allow for the fact that patients
39
40 are often seen in practices outside of their ZIP code of residence.
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50 Falsification tests

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52 To reduce the possibility that observed associations due to other unmeasured
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54 characteristics of the area, rather than the specific area resource tested, we also
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3 conducted falsification analyses. To do this, we used the same modeling approach as
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5 above, but tested for the association between area after school resources for
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7 children and the outcome of interest. Our reasoning was that, since there was
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9 unlikely to be any direct effect of after school resources on adult health, any
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11 observed association would be due to unmeasured area-characteristics not
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13 appropriately adjusted for in our model (such as high levels of civic engagement or
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15 community organization, or other beneficial resources).
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22 Variations in clinical management

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24 To help explore whether variations in the intensity of clinical management could
25
26 explain whether community resources were associated with health outcomes, we
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28 also used the above modeling approach to test whether area resources were
29
30 associated with SBP in those *without* a diagnosis of hypertension. The primary care
31
32 network in the study has quality improvement program that emphasize the
33
34 importance of SBP, LDL, and HbA1c control in appropriate clinical populations.
35
36 Since BMI (in any population) and SBP control in those without a diagnosis of
37
38 hypertension are not included in these programs, we reasoned that area-resources
39
40 may be more important when clinicians are not intensively attempting to impact an
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42 outcome. We focused on BMI and systolic blood pressure among those *without*
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44 hypertension for this because BMI and SBP are routinely measured at all practice
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46 visits for all patients.
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3 Because of its mechanistically plausible relationship with BMI, we used the
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5 association between ZIP-level food resources and BMI as the primary outcome, with
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7 secondary analyses being the associations between other VSURF selected area-
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9 resources and clinical outcomes.
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15 Robustness checks

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19 In addition to the main analyses, we conducted a series of robustness checks that
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21 examined whether different specifications of resources in the area (e.g. resources
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23 per capita or resources per capita living in poverty) or different functional forms
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25 (e.g. including polynomial terms or using splines) would alter the observed
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27 associations between area-level resources and outcomes. We also conducted
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29 analyses restricted to those with indicators of lower socioeconomic status (high
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31 school diploma or lower educational attainment, living in a ZIP where > 15% of
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33 individuals are in poverty) to ensure the results were applicable to those most likely
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35 to utilize the resources studied.
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43 A p-value of < 0.05 was taken to indicate statistical significance. Analyses were
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45 conducted in SAS Version 9.4 (Cary, NC), Stata 14 (College Station, TX), and R
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47 version 3.3.4 (Vienna, Austria).
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52 Results

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3 Overall, 123,355 participants were included in the study. All participants were
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5 eligible for the BMI analyses. Based on inclusion criteria, 43,509 were included in
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7 the hypertension analyses, 46,940 were included in the LDL analyses, and 13,127
8
9 were included in the diabetes analyses. Demographic characteristics of the overall
10
11 sample are presented in Table 1. Demographic characteristics of the samples used in
12
13 the hypertension, LDL cholesterol, and diabetes analyses are presented in eTables 1-
14
15 3. Overall, the mean age was 52.4 (SD 16.9) years, the sample was 41.5% male,
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17 82.1% non-Hispanic white, 5.8% non-Hispanic black, and 6.5% Hispanic. The
18
19 median number of years participants were followed in our network was 9
20
21 (intraquartile range (IQR): 3, 10), and the median number change of address per
22
23 year followed was 0.1 (IQR 0.1, 0.25), suggesting that participants resided at their
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25 current address for the majority of their time in our network.
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34 In general, individuals living in areas with more resources were less well-off (eTable
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36 4). Maps depicting the distribution of the resources are presented in Figure 1 and
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38 eFigures 2-3.
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43 The mean BMI in the sample was 27.8 (SD 6.2) kg/m². In the hypertension analyses,
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45 the mean BP was 131.6 (SD 15.8) mmHg. In the LDL analyses, the mean LDL was
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47 102.9 (SD 39.8) mg/dL, and in the diabetes analyses the mean HbA1c was 7.1 (SD
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49 1.5)%.
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3 Among geographic levels assessed, all resources selected were at the ZIP level
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5 (Table 2). For the BMI analyses, the selected resources were ZIP level food
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7 resources, ZIP level employment resources, and ZIP level nutrition resources. For
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9 hypertension analyses, the selected resources were ZIP housing and ZIP nutrition
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11 resources. For LDL analyses, the only selected resource was ZIP nutrition resources.
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13 For diabetes analyses, the selected resources were ZIP mental health and ZIP
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15 substance use resources.
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22 For the BMI analyses, we tested the association between selected resources and
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24 BMI, adjusting for the factors described in the statistical analysis section, and
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26 accounting for clustering at the clinic and ZIP level with multi-level linear mixed
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28 models. We found that resources associated with lower BMI included more food
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30 resources (-0.08 kg/m² per additional resource, 95% Confidence Interval[CI] -0.13
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32 to -0.03 kg/m², p= .001), employment resources (-0.05 kg/m², 95%CI -0.11 to -0.002
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34 kg/m², p=.04), and nutrition resources (-0.07 kg/m², 95%CI -0.13 to -0.01 kg/m²,
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36 p=.02) (full models for these and all robustness checks in eAppendix tables 5-16).
37
38 Table 3 compares mean BMI and obesity prevalence at selected numbers of
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40 resources, adjusted for the other factors in the model. For example, the mean BMI in
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42 neighborhoods with the median (0) number of food resources was 27.8 kg/m²,
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44 while the mean BMI in neighborhoods in the 75th percentile (3 resources) was 27.5
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46 kg/m², and the 90th percentile (8 resources) was 27.1 kg/m². Falsification tests
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48 found the expected lack of association between afterschool resources and BMI
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50 (p=.67).
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5 Robustness checks found that our results did not vary substantially with other
6 specifications of area-level resources (eTables 5-7).
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12 In the hypertension analyses, neither housing resources (-0.05 mm Hg per
13 additional resource, 95%CI -0.16 to 0.06 mm Hg, $p=.41$) nor nutrition resources
14 (0.01 mm Hg, 95%CI -0.13 to 0.16 mm Hg, $p=.87$) were associated with systolic
15 blood pressure after adjustment for individual level and area level characteristics. In
16 LDL analyses, nutrition resources (0.10 mg/dL per additional resource, 95%CI -0.36
17 to 0.55 mg/dL, $p=.67$) were not associated with LDL cholesterol in adjusted models.
18
19 In diabetes analyses, neither substance abuse resources (-0.003% per additional
20 resource, 95%CI -0.03 to 0.02%, $p=.86$) nor mental health resources were
21 associated with HbA1c (-0.003 %, 95%CI -0.03 to 0.02%, $p=.76$).
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36 In analyses looking at systolic blood pressure among those without a diagnosis of
37 hypertension (i.e., those with no reason for clinical management of blood pressure),
38 food resources were associated with lower systolic blood pressure in linear mixed
39 models adjusted for the same factors as above (-0.08 mm Hg per additional
40 resource, 95%CI -0.15 to -0.01 mm Hg, $p=.03$). Mean systolic blood pressure was
41 approximately 1 mm Hg lower at the 95th percentile (118.9 mm Hg) of food
42 resources compared with the 50th percentile (119.8 mm Hg).
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54 Full models for all analyses are presented in eTables 8-16.
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Discussion

This study assessed the relationship among area resources and cardiometabolic risk factors. We found that increasing numbers of food, employment, and nutrition resources was associated with lower BMI, and lower systolic blood pressure among those without hypertension. The magnitude of the difference was meaningful at the population level, as the 0.7 kg/m² difference in BMI between individuals in a well-resourced versus poorly resourced ZIP is similar to the 0.6 increase kg/m² in BMI in the overall U.S. population from 2006 to 2016.²³

Conversely, we found that area resources were not associated with systolic blood pressure among those with hypertension, LDL cholesterol among those with an indication for LDL lowering, or hemoglobin A1c among those with diabetes. This suggests that the relationship between area resources and cardiometabolic risk factors may vary based on whether these factors are targets of intensive clinical management.

This study enhances our knowledge regarding the association of area-level factors and cardiometabolic risk factors. Prior studies have consistently found that adverse area-level factors, such as poverty, are associated with increased cardiometabolic risk, even when adjusting for individual-level factors, such as income.^{2,24-26}

However, we did not know whether the presence of area resources that might

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2
3 plausibly support health, such as food and nutrition resources, would be associated
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5 with lower cardiometabolic risk.
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10 The positive and negative associations between community resources and
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12 cardiometabolic risk factors may have important public health implications. The
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14 association between increased area resources and lower BMI suggests that efforts to
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16 help link patients to community resources, and to help improve the resources
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18 landscape within communities, may be a successful strategy for improving
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20 population health, particularly for risk factors such as BMI where clinical
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22 management may not be prioritized.^{10,11,27} This is reinforced by the finding that SBP,
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24 among those without hypertension, is lower in those living in areas with more
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26 resources. Since SBP does not come under clinical management for those without
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28 hypertension, this finding supports the potential for area resources to impact
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30 population health, and is consistent with guidelines that recommend lifestyle, rather
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32 than pharmacologic, approaches to pre-hypertension treatment.²⁸ Future work in
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34 this area should investigate whether interventions that link individuals to area
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36 resources show clinical benefits.
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45 Our finding should be interpreted in light of several limitations. We did not have
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47 access to data regarding use of the resources. However, we did employ a multi-level
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49 modeling framework, consisting of both individual-level and area-level
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51 measurement, to avoid issues of ecologic fallacy. Next, our study was cross-
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53 sectional, and thus we cannot establish time-ordering between the exposure and the
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3 cardiometabolic outcomes. However, we think it is less likely that lower BMI would
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5 drive individuals into areas with more resources than vice versa, as areas with
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7 higher resources tended to have other adverse features, such as lower income and
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9 higher poverty, which are likely more salient considerations for those choosing
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11 where to live. Finally, because of the relatively high residential stability within this
12
13 primary care population, we only examined the association between current area of
14
15 residence and the study outcomes. However, for those who do move, this could lead
16
17 to misclassification, which would tend to bias results to the null. These limitations
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19 are balanced by several strengths. We had access to a detailed mapping of area
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21 resources, along with detailed individual-level health information. Further, in
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23 addition to the multi-level framework we used, the use of falsification tests
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25 demonstrated that unadjusted area-level factors are not likely to explain the
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27 observed results.
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36 In summary, ZIP-level food, employment, and nutrition resources were associated
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38 with BMI differences that were clinically meaningfully and statistically significant.
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40 Further, the association between area resources and cardiometabolic risk factors
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42 differed based on the specific risk factor. Investing in area resources and linkage
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44 programs may be an important way to help reduce cardiometabolic risk for
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46 vulnerable individuals, especially for situations not under intensive clinical
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48 management.
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Competing Interest Statement: All authors declare they have nothing to disclose

Guarantor: Seth A. Berkowitz had full access to all of the data in the study and takes full responsibility for the work as a whole, including the study design, access to data, the integrity of the data, the accuracy of the data analysis, and the decision to submit and publish the manuscript.

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Data Sharing Statement: Statistical code will be available concurrent with publication from <http://saberkowicz.web.unc.edu/statistical-code/>. Owing to privacy concerns, study data cannot be made publically available. Study Protocol: Not available.

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Table 1: Demographics of study sample

	N=123,355
	Mean (SD) or n (%)
Age	52.42 (16.89)
Male	51665 (41.9)
Race/ethnicity	
Asian/Multi/Other	6880 (5.6)
Non-Hispanic Black	7203 (5.8)
Hispanic	8039 (6.5)
Non-Hispanic White	101233 (82.1)
Education	
College or >	56302 (45.6)
High School Diploma	36572 (29.6)
Less than High School Diploma	18051 (14.6)
Unknown/Declined	12430 (10.1)
Insurance	
Private	75787 (61.4)
Medicare and Medicaid	8602 (7.0)
Medicaid	20934 (17.0)
Medicare	17911 (14.5)
Self-pay	121 (0.1)
English is Primary Language	112720 (91.4)
History of Hypertension	43509 (35.3)
History of Coronary Heart Disease	9275 (7.5)
History of Diabetes Mellitus	13127 (10.6)
History of Depression	10300 (8.3)
History of Osteoarthritis	23707 (19.2)
Charlson Comorbidity Score	1.72 (2.23)
Clinic Visits	6.57 (5.77)
Clinic Connectedness	
Connected to specific physician	80345 (65.1)
Connected to specific practice	34018 (27.6)
Other	8992 (7.3)
Lives in Urban Area	91095 (96.4)
ZIP-level Unemployment Rate, %	4.71 (1.60)
ZIP-level Median Household Income, \$	82309.16 (31758.79)
ZIP-level Poverty Rate, %	8.70 (6.72)
ZIP-level Segregation*	69.51 (21.05)
Body Mass Index, kg/m ²	27.84 (6.24)
Systolic Blood Pressure, mm Hg	124.36 (14.96)

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LDL cholesterol, mg/dL	110.83 (39.95)
Hemoglobin A1c, %	5.94 (1.22)

*Segregation index is a dissimilarity measure of the extent to which groups other than non-Hispanic whites are distributed like non-Hispanic whites. 0 represents complete integration and 100 represents complete segregation.

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Table 2: Distribution of Selected Resources

BMI Analyses							
Resource*	Minimum	25 th Percentile	50 th Percentile	75 th Percentile	90 th Percentile	95 th Percentile	Maximum
Food	0	0	0	3	8	11	27
Employment	0	0	0	4	13	18	33
Nutrition	0	0	0	3	6	12	21
Hypertension Analyses							
Housing	0	0	0	2	8	8	23
Nutrition	0	0	0	3	6	12	21
LDL Analyses							
Nutrition	0	0	0	3	6	12	21
Diabetes Analyses							
Mental health	0	0	0	2	5	6	21
Substance use resources	0	0	1	2	5	6	23

*All resources assessed at ZIP level

Table 3: Estimated BMI, in kg/m², by resource level

ZIP-level Food Resources	
50 th Percentile	27.78
75 th Percentile	27.53
90 th Percentile	27.11
95 th Percentile	26.85
ZIP-level Employment Resources	
50 th Percentile	27.78
75 th Percentile	27.56
90 th Percentile	27.07
95 th Percentile	26.80
ZIP-level Nutrition Resources	
50 th Percentile	27.75
75 th Percentile	27.54
90 th Percentile	27.32
95 th Percentile	26.89

Figure 1: Food Resource Density by ZIP

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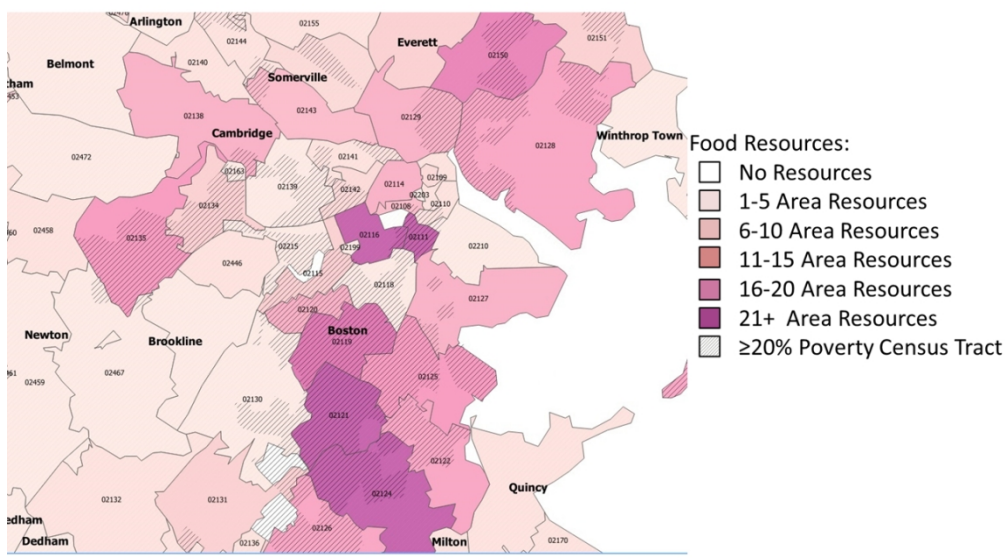


Figure 1

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3 eAppendix for Association Between Area Resources and Cardiometabolic Risk: A Machine
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Technical Appendix

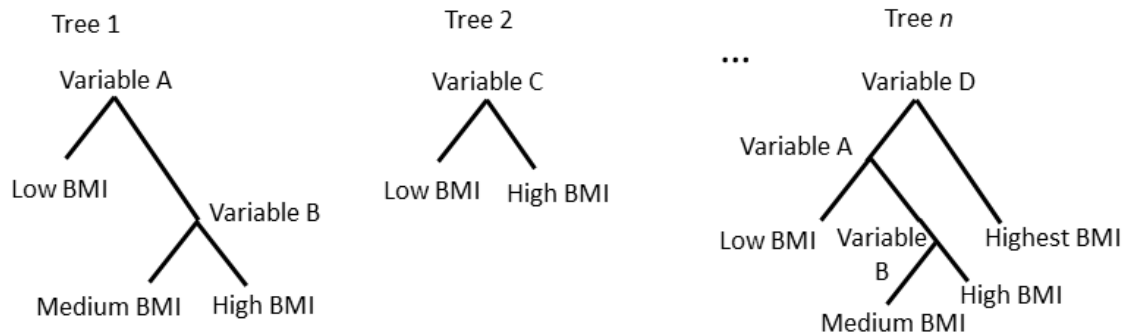
VSURF

The foundation of the VSURF technique is the decision tree (eFigure 1).²¹ To construct a single decision tree, the procedure selects a random subset of variables from the total number of available variables, and selects a variable that best explains the variation in outcome of a bootstrap resample drawn from the derivation sample. For the next split, the variable that best explains the variation within each 'branch' of the tree created in the first split is selected. This process is continued until optimal separation is achieved. A 'forest' is grown by repeating this process 2000 times, each time randomly drawing a subset of variables and bootstrap resample of the derivation cohort. In the VSURF procedure, 50 forests of 2000 trees were grown in the initial 'thresholding' step, which focuses on removing irrelevant variables. Then, 25 forests of 2000 trees, using the remaining variables, were grown to select all variables associated with the response. Finally, 25 forests of 2000 trees were grown, selecting among the remaining variables to eliminate redundancy. After all three steps were completed, we selected up to the top three area resources, as indicated by variable importance factors in the final step, for hypothesis testing in the independent, 'testing' sample.

A major advantage of VSURF is that it directly addresses the correlation among variables, as the single best variable is selected at each split and thus the explanatory power is not divided amongst two or more related variables, as in linear regression. Secondly, VSURF allows one to screen through a number of candidate variables while preserving type I error rate, as statistical

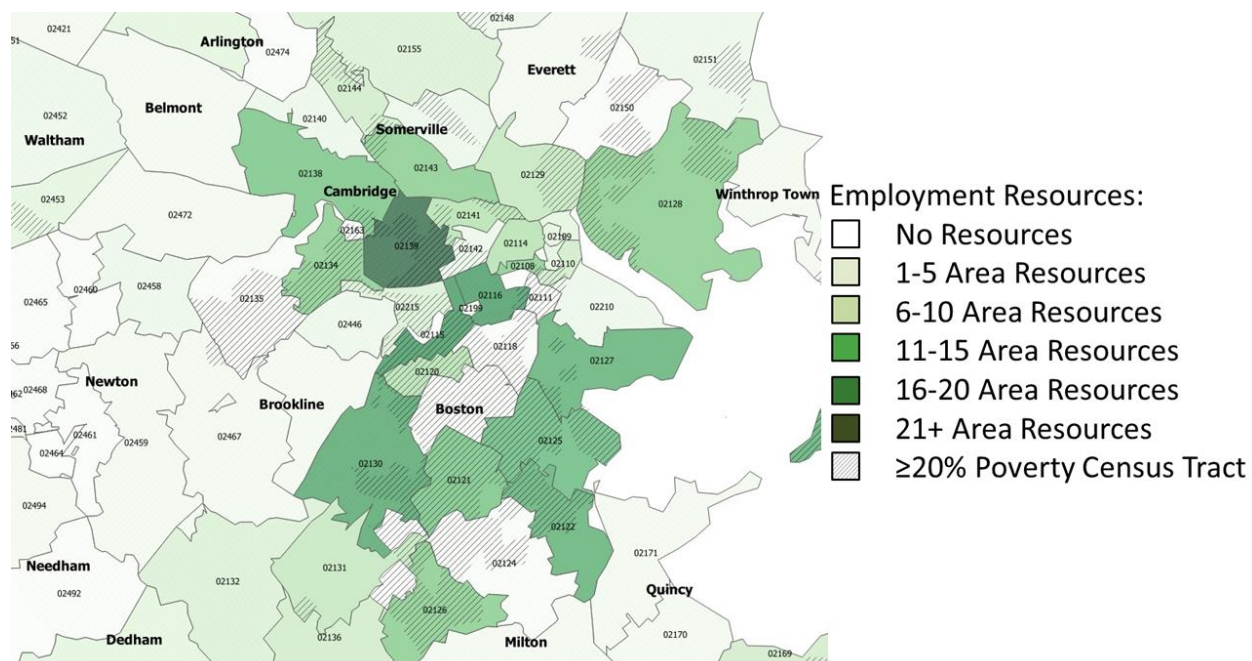
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3 significance testing is not used in the selection of variables, unlike p-value-based selection
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eFigure 1: Depiction of the Variable Selection Using Random Forest (VSURF) Method



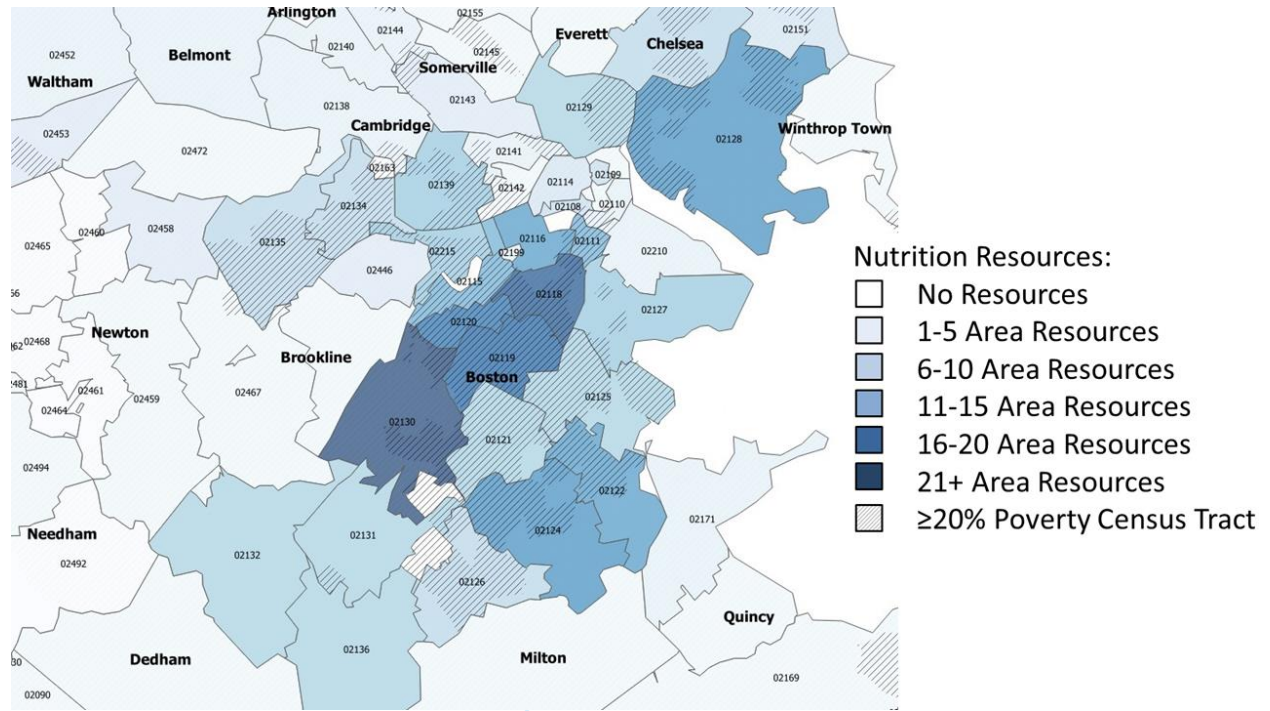
From a random subset of variables and a bootstrap resample of individuals in the derivation cohort, a decision tree that optimally splits the sample is created. This process is repeated in a second bootstrap resample with a second randomly selected subset of variables, and so on until n trees ($n=2000$ in this study) are aggregated to create one forest. The forest-growing procedure is repeated 50 times. Then, using variable importance factors, which indicate the variables that are most useful in minimizing the error of predicted values in the 'out-of-bag' sample (those observations that, due to chance, were not selected in the bootstrap resample). After removing the least important variables, the entire process is repeated again, this time growing 25 forests of 2000 trees, in the 'interpretation' step, which focuses on selecting all variables associated with the response. Finally, to deal with correlations between variables, the process is repeated again, growing 25 more forests of 2000 trees, in the 'prediction' step, which focuses on removing redundancy in the final set of variables.

eFigure 2: Employment Resources by ZIP



Review only

eFigure 3: Nutrition Resources by ZIP



review only

eTable 1: Demographics for Hypertension Study Sample

	N=43,509
	Mean (SD) or n (%)
Age	64.67 (14.05)
Male	21299 (49.0)
Race/ethnicity	
Asian/Multi/Other	1755 (4.0)
Non-Hispanic Black	3138 (7.2)
Hispanic	1983 (4.6)
Non-Hispanic White	36633 (84.2)
Education	
College or >	15660 (36.0)
High School Diploma	15900 (36.5)
Less than High School Diploma	7422 (17.1)
Unknown/Declined	4527 (10.4)
Insurance	
Private	17256 (39.7)
Medicare and Medicaid	6200 (14.2)
Medicaid	6292 (14.5)
Medicare	13756 (31.6)
Self-pay	5 (0.0)
English is Primary Language	39492 (90.8)
History of Coronary Heart Disease	8373 (19.2)
History of Diabetes Mellitus	11085 (25.5)
History of Depression	4745 (10.9)
History of Osteoarthritis	14931 (34.3)
Charlson Comorbidity Score	3.22 (2.57)
Clinic Visits	9.58 (6.77)
Clinic Connectedness	
Connected to specific physician	36233 (83.3)
Connected to specific practice	6978 (16.0)
Other	298 (0.7)
Lives in Urban Area	32075 (96.4)
ZIP-level Unemployment Rate, %	4.85 (1.63)
ZIP-level Median Household Income, \$	80247.61 (31190.75)
ZIP-level Poverty Rate, %	8.67 (6.63)
ZIP-level Segregation	69.19 (21.92)
Body Mass Index, kg/m ²	29.68 (6.40)
History of Obesity	19314 (45.2)
Systolic Blood Pressure, mm Hg	131.60 (15.75)

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LDL cholesterol, mg/dL	102.73 (39.82)
Hemoglobin A1c, %	6.25 (1.34)

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eTable 2: Demographics for LDL Study Sample

	N=46940
	Mean (SD) or n (%)
Age	63.96 (14.33)
Male	22916 (48.8)
Race/ethnicity	
Asian/Multi/Other	1971 (4.2)
Non-Hispanic Black	3401 (7.2)
Hispanic	2285 (4.9)
Non-Hispanic White	39283 (83.7)
Education	
College or >	16940 (36.1)
High School Diploma	17032 (36.3)
Less than High School Diploma	8075 (17.2)
Unknown/Declined	4893 (10.4)
Insurance	
Private	18909 (40.3)
Medicare and Medicaid	6561 (14.0)
Medicaid	7169 (15.3)
Medicare	14296 (30.5)
Self-pay	5 (0.0)
English is Primary Language	42468 (90.5)
History of Hypertension	43509 (92.7)
History of Coronary Heart Disease	9275 (19.8)
History of Diabetes Mellitus	13127 (28.0)
History of Depression	5160 (11.0)
History of Osteoarthritis	15695 (33.4)
Charlson Comorbidity Score	3.14 (2.54)
Clinic Visits	9.46 (6.71)
Clinic Connectedness	
Connected to specific physician	38851 (82.8)
Connected to specific practice	7746 (16.5)
Other	343 (0.7)
Lives in Urban Area	34532 (96.4)
ZIP-level Unemployment Rate, %	4.86 (1.63)
ZIP-level Median Household Income, \$	80079.26 (31173.63)
ZIP-level Poverty Rate, %	8.72 (6.64)
ZIP-level Segregation	68.98 (21.98)
Body Mass Index, kg/m ²	29.63 (6.42)
History of Obesity	20611 (44.7)
Systolic Blood Pressure, mm Hg	130.88 (15.75)

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LDL cholesterol, mg/dL	102.85 (39.81)
Hemoglobin A1c, %	6.28 (1.36)

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eTable 3: Demographics for Diabetes Study Sample

	N=13127
	Mean (SD) or n (%)
Age	64.12 (14.10)
Male	6722 (51.2)
Race/ethnicity	
Asian/Multi/Other	729 (5.6)
Non-Hispanic Black	1415 (10.8)
Hispanic	986 (7.5)
Non-Hispanic White	9995 (76.1)
Education	
College or >	3691 (28.1)
High School Diploma	5115 (39.0)
Less than High School Diploma	3085 (23.5)
Unknown/Declined	1236 (9.4)
Insurance	
Private	4247 (32.4)
Medicare and Medicaid	2609 (19.9)
Medicaid	2654 (20.2)
Medicare	3617 (27.6)
Self-pay	0 (0.0)
English is Primary Language	11138 (84.8)
History of Hypertension	11085 (84.4)
History of Coronary Heart Disease	3316 (25.3)
History of Diabetes Mellitus	13127 (100.0)
History of Depression	1685 (12.8)
History of Osteoarthritis	4605 (35.1)
Charlson Comorbidity Score	4.34 (2.94)
Clinic Visits	11.59 (7.52)
Clinic Connectedness	
Connected to specific physician	10778 (82.1)
Connected to specific practice	2234 (17.0)
Other	115 (0.9)
Lives in Urban Area	9467 (97.4)
ZIP-level Unemployment Rate, %	5.24 (1.67)
ZIP-level Median Household Income, \$	72660.30 (28239.05)
ZIP-level Poverty Rate, %	10.19 (6.83)
ZIP-level Segregation	63.62 (23.80)
Body Mass Index, kg/m ²	31.48 (6.85)
History of Obesity	7427 (57.7)
Systolic Blood Pressure, mm Hg	130.17 (16.09)

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LDL cholesterol, mg/dL	89.25 (37.45)
Hemoglobin A1c, %	7.08 (1.52)

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eTable 4: Demographics of study sample by number of food resources in ZIP code tabulation area

	0 food resources	1 to 7 food resources	≥8 food resources	p
	N=65011	N=42794	N=13028	
	Mean (SD) or n (%)	Mean (SD) or n (%)	Mean (SD) or n (%)	
Age	53.93 (16.13)	51.05 (17.69)	47.95 (16.92)	<0.001
Male	28050 (43.1)	17330 (40.5)	5163 (39.6)	<0.001
Race/ethnicity				<0.001
Asian/Multi/Other	3559 (5.5)	2501 (5.8)	709 (5.4)	
Non-Hispanic Black	2553 (3.9)	2710 (6.3)	1605 (12.3)	
Hispanic	2306 (3.5)	2859 (6.7)	2707 (20.8)	
Non-Hispanic White	56593 (87.1)	34724 (81.1)	8007 (61.5)	
Education				<0.001
College or >	31782 (48.9)	18895 (44.2)	4837 (37.1)	
High School Diploma	18400 (28.3)	13355 (31.2)	3767 (28.9)	
Less than High School Diploma	7373 (11.3)	6762 (15.8)	3449 (26.5)	
Unknown/Declined	7456 (11.5)	3782 (8.8)	975 (7.5)	
Insurance				<0.001
Private	44051 (67.8)	24062 (56.2)	6600 (50.7)	
Medicare and Medicaid	3485 (5.4)	3551 (8.3)	1188 (9.1)	
Medicaid	7319 (11.3)	9011 (21.1)	4075 (31.3)	
Medicare	10128 (15.6)	6093 (14.2)	1149 (8.8)	
Self-pay	28 (0.0)	77 (0.2)	16 (0.1)	
English is Primary Language	61559 (94.7)	38982 (91.1)	9923 (76.2)	<0.001
History of Hypertension	22195 (34.1)	15367 (35.9)	4342 (33.3)	<0.001
History of Coronary Heart Disease	4663 (7.2)	3385 (7.9)	817 (6.3)	<0.001
History of Cerebrovascular Disease	1628 (2.5)	1148 (2.7)	316 (2.4)	0.114
History of Congestive Heart Failure	1941 (3.0)	1793 (4.2)	460 (3.5)	<0.001
History of Diabetes Mellitus	5735 (8.8)	4757 (11.1)	1735 (13.3)	<0.001
History of Depression	4598 (7.1)	4024 (9.4)	1377 (10.6)	<0.001
History of Osteoarthritis	12179 (18.7)	8386 (19.6)	2331 (17.9)	<0.001
Charlson Comorbidity Score	1.70 (2.17)	1.72 (2.28)	1.56 (2.15)	<0.001
Clinic Visits	5.93 (5.18)	7.14 (6.21)	7.19 (6.11)	<0.001
Clinic Connectedness				<0.001
Connected to specific physician	41292 (63.5)	28457 (66.5)	8593 (66.0)	
Connected to specific practice	14727 (22.7)	14337 (33.5)	4435 (34.0)	
Other	8992 (13.8)	0 (0.0)	0 (0.0)	
Lives in Urban Area	52165 (94.3)	29291 (99.4)	7118 (99.9)	<0.001
ZIP-level Unemployment Rate, %	4.27 (1.41)	4.89 (1.51)	5.82 (1.83)	<0.001
ZIP-level Median Household Income, \$	96937.11 (34242.61)	71648.83 (21514.21)	58606.22 (17651.59)	<0.001

ZIP-level Poverty Rate, %	4.91 (4.58)	11.12 (6.26)	15.94 (5.58)	<0.001
ZIP-level Segregation	80.59 (15.85)	65.17 (15.29)	39.16 (20.13)	<0.001
Body Mass Index, kg/m ²	27.64 (6.03)	27.82 (6.34)	28.30 (6.63)	<0.001
History of Obesity	18693 (30.1)	12765 (30.8)	4148 (33.2)	<0.001
Systolic Blood Pressure, mm Hg	124.47 (14.92)	124.27 (15.03)	123.44 (14.80)	<0.001
LDL cholesterol, mg/dL	112.17 (42.48)	109.92 (37.14)	108.83 (35.34)	<0.001
Hemoglobin A1c, %	5.86 (1.12)	5.98 (1.25)	6.13 (1.43)	<0.001

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1
2
3 Robustness checks (eTable 5-7)
4
5
6

7 Results from analyses, adjusted for the same factors as in main model presented in the manuscript,
8 comparing the association of food resources and BMI with different specifications of ZIP-level food
9 resources (count, count per capita, and count per capita living in poverty) show that the association
10 between more area food resources and lower BMI is robust to different specifications of number of
11 resources
12

13
14 eTable 5: Analyses comparing the association of food resources and BMI with different specifications
15 of area-resources

16 Estimated difference in BMI associated 17 with 1 additional ZIP-level resource (95% 18 CI), kg/m ² 19 (main model from manuscript)	20 Estimated difference in 21 BMI associated with 1 22 additional ZIP-level 23 resource per 10000 people 24 (95% CI), kg/m ²	25 Estimated difference in BMI 26 associated with 1 additional 27 ZIP-level resource per 10000 28 people living in poverty 29 (95% CI), kg/m ²
30 -0.08 (-0.13 to -0.03)	31 -0.19 (-0.29 to -0.085)	32 -0.02 (-0.03 to -0.01)

33 Analyses, adjusted for the same factors as in main model presented in the manuscript, including a
34 quadratic and/or cubic term, or restricted cubic splines, to represent the number of ZIP-level resources
35 resulted in worse model fit by Akaike information criterion and Bayes information criterion, suggesting
36 that a linear approximation of the relationship between ZIP-level resources and the modeled outcome is
37 reasonable.
38

39 eTable 6: Model fit statistics from different specifications of ZIP-level food resources

40	41 Akaike information criterion 42 (smaller represents better fit)	43 Bayes information criterion 44 (smaller represents better fit)
45 Linear term only	46 468646.6	47 468640.6
48 Linear plus quadratic	49 468656.5	50 468650.5
51 Linear, quadratic, and cubic	52 468667.8	53 468661.8
54 Restricted cubic spline	55 468656.0	56 468650.0

57 Analyses, adjusted for the same factors as in main model presented in the manuscript, restricted to
58 those with indicators of lower socioeconomic status show that the estimates for the association
59 between additional ZIP-level food resources and BMI are slightly larger than in the overall population,
60 which is consistent with the idea that these resources are beneficial for those with lower socioeconomic
61 status

62 eTable 7: Analyses of association between ZIP-level food resources and body mass index, restricted to
63 those with indicators of lower socioeconomic status
64

Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), kg/m ² (main model from manuscript)	Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), restricted to those with high school diploma or lower educational attainment, kg/m ²	Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), restricted to those living in ZIP with > 15% living in poverty, kg/m ²
-0.08 (-0.13 to -0.03)	-0.09 (-0.15 to -0.04)	-0.11 (-0.17 to -0.06)

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eTable 8: Full models for association between ZIP-level food resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.2196	1.1796	<.0001	25.9071	30.5320
ZIP-level food resources	-0.08429	0.02512	0.0010	-0.1340	-0.03460
ZIP-level afterschool resources	0.009484	0.02203	0.6674	-0.03404	0.05301
Age, years	-0.04950	0.002011	<.0001	-0.05344	-0.04556
Female	-1.3794	0.04395	<.0001	-1.4656	-1.2933
Race/ethnicity					
Asian/Multi/Other	-2.5117	0.09328	<.0001	-2.6945	-2.3288
Non-Hispanic Black	0.9600	0.09753	<.0001	0.7688	1.1511
Hispanic	0.7277	0.1081	<.0001	0.5157	0.9396
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2793	0.07082	<.0001	-0.4181	-0.1404
High School Diploma	0.09622	0.07549	0.2025	-0.05175	0.2442
Less than High School Diploma	0.3871	0.09117	<.0001	0.2084	0.5658
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1890	1.0208	0.8531	-1.8118	2.1898
Medicare and Medicaid	0.06964	1.0240	0.9458	-1.9374	2.0767
Medicaid	0.6961	1.0215	0.4956	-1.3061	2.6983
Medicaid	-0.4968	1.0230	0.6272	-2.5019	1.5083
Self-pay	reference	n/a	n/a	n/a	n/a
English is Primary Language	0.7128	0.09604	<.0001	0.5246	0.9011
History of Hypertension	2.7291	0.05550	<.0001	2.6203	2.8379
History of Coronary Heart Disease	-0.4141	0.08601	<.0001	-0.5827	-0.2455
History of Diabetes Mellitus	2.4217	0.07471	<.0001	2.2752	2.5681

eTable 8: Full models for association between ZIP-level food resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	0.5488	0.07350	<.0001	0.4048	0.6929
History of Osteoarthritis	1.3188	0.05467	<.0001	1.2116	1.4260
Charlson Comorbidity Score	0.06713	0.01268	<.0001	0.04227	0.09198
Clinic Visits	-0.00068	0.004383	0.8770	-0.00927	0.007911
Clinic Connectedness					
Connected to specific physician	0.3184	0.05024	<.0001	0.2200	0.4169
Connected to specific practice	reference	n/a	n/a	n/a	n/a
Lives in Urban Area	0.2640	0.1580	0.0949	-0.04583	0.5739
Lives in Area with Low Physical Food Access	0.09426	0.07794	0.2265	-0.05851	0.2470
Percentage of Area Living in Group Quarters	-0.00020	0.000060	0.0009	-0.00032	-0.00008
Lives in Area with Low Vehicle Access	0.1189	0.05577	0.0331	0.009564	0.2282
ZIP-level Unemployment Rate	0.2608	0.03829	<.0001	0.1855	0.3361
ZIP-level Median Household Income	-0.00001	1.936E-6	<.0001	-0.00002	-8.81E-6
ZIP-level Poverty Rate	-0.03254	0.01370	0.0183	-0.05952	-0.00555
ZIP-level Segregation	0.002536	0.003897	0.5158	-0.00514	0.01021

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.1779	1.1847	<.0001	25.8554	30.5004
ZIP-level employment resources	-0.05415	0.02624	0.0407	-0.1060	-0.00231

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
ZIP-level afterschool resources	0.01083	0.03215	0.7366	-0.05269	0.07436
Age, years	-0.04951	0.002011	<.0001	-0.05345	-0.04557
Female	-1.3795	0.04395	<.0001	-1.4656	-1.2933
Race/ethnicity					
Asian/Multi/Other	-2.5089	0.09330	<.0001	-2.6918	-2.3260
Non-Hispanic Black	0.9669	0.09755	<.0001	0.7757	1.1581
Hispanic	0.7300	0.1081	<.0001	0.5181	0.9420
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2787	0.07083	<.0001	-0.4175	-0.1399
High School Diploma	0.09646	0.07549	0.2013	-0.05150	0.2444
Less than High School Diploma	0.3880	0.09117	<.0001	0.2093	0.5667
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1930	1.0208	0.8500	-1.8078	2.1938
Medicare and Medicaid	0.07527	1.0240	0.9414	-1.9318	2.0823
Medicaid	0.7010	1.0215	0.4926	-1.3012	2.7032
Medicaid	-0.4922	1.0230	0.6304	-2.4973	1.5128
Self-pay	reference	n/a	n/a	n/a	n/a
English is Primary Language	0.7126	0.09604	<.0001	0.5243	0.9008
History of Hypertension	2.7296	0.05550	<.0001	2.6208	2.8383
History of Coronary Heart Disease	-0.4138	0.08601	<.0001	-0.5824	-0.2452
History of Diabetes Mellitus	2.4215	0.07471	<.0001	2.2751	2.5680
History of Depression	0.5493	0.07350	<.0001	0.4052	0.6933
History of Osteoarthritis	1.3190	0.05467	<.0001	1.2118	1.4261

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Charlson Comorbidity Score	0.06713	0.01268	<.0001	0.04227	0.09198
Clinic Visits	-0.00069	0.004383	0.8744	-0.00928	0.007897
Clinic Connectedness					
Connected to specific physician	0.3181	0.05024	<.0001	0.2197	0.4166
Connected to specific practice	reference	n/a	n/a	n/a	n/a
Lives in Urban Area	0.2569	0.1589	0.1059	-0.05456	0.5684
Lives in Area with Low Physical Food Access	0.09945	0.07799	0.2023	-0.05342	0.2523
Percentage of Area Living in Group Quarters	-0.00019	0.000060	0.0013	-0.00031	-0.00008
Lives in Area with Low Vehicle Access	0.1198	0.05586	0.0320	0.01027	0.2293
ZIP-level Unemployment Rate	0.2601	0.03946	<.0001	0.1825	0.3377
ZIP-level Median Household Income	-0.00001	1.988E-6	<.0001	-0.00002	-8.84E-6
ZIP-level Poverty Rate	-0.03147	0.01401	0.0255	-0.05905	-0.00389
ZIP-level Segregation	0.003079	0.003968	0.4385	-0.00473	0.01089

eTable 10: Full models for association between ZIP-level nutrition resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.1161	1.1836	<.0001	25.7958	30.4364
ZIP-level nutrition resources	-0.07146	0.03122	0.0234	-0.1331	-0.00980
ZIP-level afterschool resources	0.002639	0.02650	0.9208	-0.04967	0.05495
Age, years	-0.04949	0.002011	<.0001	-0.05344	-0.04555
Female	-1.3792	0.04395	<.0001	-1.4654	-1.2931
Race/ethnicity					
Asian/Multi/Other	-2.5116	0.09329	<.0001	-2.6944	-2.3287
Non-Hispanic Black	0.9650	0.09756	<.0001	0.7738	1.1562
Hispanic	0.7272	0.1081	<.0001	0.5152	0.9392
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2787	0.07082	<.0001	-0.4175	-0.1399
High School Diploma	0.09695	0.07549	0.1991	-0.05102	0.2449
Less than High School Diploma	0.3870	0.09117	<.0001	0.2083	0.5657
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1858	1.0208	0.8555	-1.8150	2.1866
Medicare and Medicaid	0.06642	1.0240	0.9483	-1.9406	2.0735
Medicaid	0.6927	1.0215	0.4977	-1.3095	2.6948
Medicaid	-0.5000	1.0230	0.6250	-2.5050	1.5051
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.7143	0.09604	<.0001	0.5261	0.9026
History of Hypertension	2.7290	0.05550	<.0001	2.6202	2.8378
History of Coronary Heart Disease	-0.4139	0.08601	<.0001	-0.5825	-0.2453
History of Diabetes Mellitus	2.4211	0.07471	<.0001	2.2747	2.5676

eTable 10: Full models for association between ZIP-level nutrition resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	0.5484	0.07350	<.0001	0.4044	0.6925
History of Osteoarthritis	1.3187	0.05467	<.0001	1.2115	1.4259
Charlson Comorbidity Score	0.06712	0.01268	<.0001	0.04227	0.09197
Clinic Visits	-0.00069	0.004383	0.8750	-0.00928	0.007900
Clinic Connectedness					
Connected to specific physician	0.3185	0.05024	<.0001	0.2200	0.4170
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.2529	0.1588	0.1113	-0.05838	0.5642
Lives in Area with Low Physical Food Access	0.1009	0.07792	0.1955	-0.05185	0.2536
Percentage of Area Living in Group Quarters	-0.00020	0.000060	0.0009	-0.00032	-0.00008
Lives in Area with Low Vehicle Access	0.1176	0.05585	0.0352	0.008130	0.2271
ZIP-level Unemployment Rate	0.2684	0.03881	<.0001	0.1921	0.3447
ZIP-level Median Household Income	-0.00001	1.972E-6	<.0001	-0.00002	-8.48E-6
ZIP-level Poverty Rate	-0.03270	0.01396	0.0199	-0.06020	-0.00521
ZIP-level Segregation	0.003113	0.003967	0.4332	-0.00470	0.01092

eTable 11: Full models for association between ZIP-level housing resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	115.70	11.1188	<.0001	93.9116	137.50
ZIP-level housing resources	-0.04612	0.05585	0.4106	-0.1567	0.06446
ZIP-level afterschool resources	-0.03286	0.04586	0.4755	-0.1240	0.05828
Age, years	0.1521	0.009429	<.0001	0.1337	0.1706
Female	-0.6839	0.1930	0.0004	-1.0622	-0.3055
Race/ethnicity					
Asian/Multi/Other	-1.2014	0.4952	0.0153	-2.1720	-0.2308
Non-Hispanic Black	2.8013	0.3960	<.0001	2.0251	3.5774
Hispanic	0.5064	0.5619	0.3675	-0.5950	1.6078
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	0.02428	0.3181	0.9392	-0.5992	0.6478
High School Diploma	0.1732	0.3236	0.5924	-0.4610	0.8074
Less than High School Diploma	0.6220	0.3914	0.1121	-0.1452	1.3893
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	8.3527	10.9765	0.4467	-13.1616	29.8671
Medicare and Medicaid	7.8728	10.9784	0.4733	-13.6453	29.3910
Medicaid	8.5660	10.9772	0.4352	-12.9499	30.0818
Medicaid	8.4728	10.9781	0.4402	-13.0447	29.9903
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.01463	0.4091	0.9715	-0.8165	0.7873
History of Coronary Heart Disease	-2.7190	0.2620	<.0001	-3.2325	-2.2055
History of Diabetes Mellitus	0.1079	0.2325	0.6426	-0.3478	0.5635
History of Depression	-0.9568	0.3076	0.0019	-1.5596	-0.3539

eTable 11: Full models for association between ZIP-level housing resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.5000	0.2009	0.0128	-0.8939	-0.1062
Charlson Comorbidity Score	-0.05959	0.04502	0.1856	-0.1478	0.02865
Clinic Visits	-0.02840	0.01601	0.0760	-0.05978	0.002975
Clinic Connectedness					
Connected to specific physician	-1.9594	0.2580	<.0001	-2.4651	-1.4538
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.2234	0.5896	0.7049	-0.9332	1.3799
Lives in Area with Low Physical Food Access	-0.6380	0.3321	0.0548	-1.2892	0.01327
Percentage of Area Living in Group Quarters	-0.00025	0.000262	0.3352	-0.00077	0.000261
Lives in Area with Low Vehicle Access	0.2689	0.2251	0.2324	-0.1725	0.7102
ZIP-level Unemployment Rate	0.1919	0.1055	0.0702	-0.01598	0.3998
ZIP-level Median Household Income	5.33E-7	4.993E-6	0.9151	-9.33E-6	0.000010
ZIP-level Poverty Rate	0.003603	0.03442	0.9168	-0.06460	0.07180
ZIP-level Segregation	-0.00127	0.01007	0.8999	-0.02117	0.01863

eTable 12: Full models for association between ZIP-level nutrition resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	115.52	11.1170	<.0001	93.7336	137.31
ZIP-level nutrition resources	0.01167	0.07270	0.8728	-0.1325	0.1559
ZIP-level afterschool resources	-0.06660	0.05852	0.2582	-0.1829	0.04971
Age, years	0.1522	0.009429	<.0001	0.1337	0.1707
Female	-0.6823	0.1930	0.0004	-1.0606	-0.3039
Race/ethnicity					
Asian/Multi/Other	-1.2077	0.4952	0.0147	-2.1782	-0.2371
Non-Hispanic Black	2.7981	0.3960	<.0001	2.0218	3.5744
Hispanic	0.5101	0.5622	0.3643	-0.5919	1.6120
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
education					
College or >	0.01868	0.3181	0.9532	-0.6048	0.6421
High School Diploma	0.1716	0.3236	0.5958	-0.4626	0.8059
Less than High School Diploma	0.6218	0.3915	0.1122	-0.1455	1.3891
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	8.3894	10.9765	0.4447	-13.1251	29.9038
Medicare and Medicaid	7.9053	10.9784	0.4715	-13.6130	29.4235
Medicaid	8.6004	10.9773	0.4334	-12.9155	30.1163
Medicaid	8.5087	10.9781	0.4383	-13.0089	30.0263
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.01592	0.4094	0.9690	-0.8183	0.7865
History of Coronary Heart Disease	-2.7161	0.2620	<.0001	-3.2295	-2.2026
History of Diabetes Mellitus	0.1087	0.2325	0.6399	-0.3469	0.5644
History of Depression	-0.9576	0.3076	0.0019	-1.5605	-0.3547

eTable 12: Full models for association between ZIP-level nutrition resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.5002	0.2009	0.0128	-0.8940	-0.1063
Charlson Comorbidity Score	-0.05975	0.04502	0.1845	-0.1480	0.02849
Clinic Visits	-0.02845	0.01601	0.0756	-0.05982	0.002932
Clinic Connectedness					
Connected to specific physician	-1.9589	0.2580	<.0001	-2.4645	-1.4532
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.1603	0.5860	0.7845	-0.9893	1.3098
Lives in Area with Low Physical Food Access	-0.5789	0.3269	0.0768	-1.2201	0.06231
Percentage of Area Living in Group Quarters	-0.00025	0.000262	0.3343	-0.00077	0.000261
Lives in Area with Low Vehicle Access	0.2662	0.2251	0.2371	-0.1752	0.7076
ZIP-level Unemployment Rate	0.2065	0.1045	0.0493	0.000612	0.4124
ZIP-level Median Household Income	1.008E-6	4.966E-6	0.8395	-8.8E-6	0.000011
ZIP-level Poverty Rate	0.003660	0.03453	0.9158	-0.06473	0.07205
ZIP-level Segregation	-0.00086	0.01007	0.9325	-0.02075	0.01904

eTable 13: Full models for association between ZIP-level nutrition resources and low density lipoprotein cholesterol

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	103.76	38.1863	0.0066	28.9153	178.61
ZIP-level nutrition resources	0.09859	0.2309	0.6699	-0.3573	0.5545
ZIP-level afterschool resources	-0.00381	0.1854	0.9837	-0.3706	0.3630
Age, years	-0.3600	0.03023	<.0001	-0.4193	-0.3008
Female	11.7432	0.5645	<.0001	10.6367	12.8497
Race/ethnicity	0	.	.	.	.
Asian/Multi/Other	-2.6927	1.4423	0.0619	-5.5197	0.1343
Non-Hispanic Black	0.7350	1.2077	0.5428	-1.6323	3.1022
Hispanic	0.3468	1.7794	0.8455	-3.1409	3.8345
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1046	0.9328	0.9107	-1.9329	1.7237
High School Diploma	-0.2598	0.9497	0.7844	-2.1212	1.6016
Less than High School Diploma	-0.8496	1.1612	0.4644	-3.1256	1.4264
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	37.5148	37.8147	0.3212	-36.6052	111.63
Medicare and Medicaid	36.1970	37.8181	0.3385	-37.9296	110.32
Medicaid	37.4872	37.8163	0.3216	-36.6360	111.61
Medicaid	35.4040	37.8171	0.3492	-38.7206	109.53
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.6482	1.2438	0.6023	-1.7897	3.0861
History of Hypertension	-4.3457	1.1538	0.0002	-6.6072	-2.0842
History of Coronary Heart Disease	-14.8429	0.7275	<.0001	-16.2689	-13.4170
History of Diabetes Mellitus	-16.1429	0.6619	<.0001	-17.4404	-14.8455

eTable 13: Full models for association between ZIP-level nutrition resources and low density lipoprotein cholesterol

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	1.0979	0.9513	0.2485	-0.7668	2.9626
History of Osteoarthritis	1.0828	0.5853	0.0643	-0.06449	2.2302
Charlson Comorbidity Score	-0.9716	0.1366	<.0001	-1.2394	-0.7038
Clinic Visits	-0.1983	0.04901	<.0001	-0.2944	-0.1023
Clinic Connectedness					
Connected to specific physician	-1.4526	0.8446	0.0855	-3.1081	0.2029
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	-0.4909	1.7202	0.7754	-3.8649	2.8831
Lives in Area with Low Physical Food Access	0.2234	1.0117	0.8252	-1.7604	2.2073
Percentage of Area Living in Group Quarters	0.001870	0.000788	0.0177	0.000325	0.003414
Lives in Area with Low Vehicle Access	-1.1732	0.6607	0.0759	-2.4686	0.1222
ZIP-level Unemployment Rate	0.1519	0.3138	0.6287	-0.4659	0.7698
ZIP-level Median Household Income	-0.00001	0.000015	0.3460	-0.00004	0.000015
ZIP-level Poverty Rate	-0.06528	0.1068	0.5418	-0.2760	0.1454
ZIP-level Segregation	-0.00654	0.03045	0.8301	-0.06656	0.05347

eTable 14: Full models for association between ZIP-level substance abuse resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	7.0576	0.3362	<.0001	6.3986	7.7166
ZIP-level substance abuse resources	-0.00251	0.01460	0.8634	-0.03113	0.02611
ZIP-level afterschool resources	0.01106	0.007376	0.1336	-0.00339	0.02552
Age, years	-0.01059	0.001940	<.0001	-0.01440	-0.00679
Female	-0.1380	0.03843	0.0003	-0.2133	-0.06263
Race/ethnicity					
Asian/Multi/Other	-0.08503	0.08123	0.2952	-0.2443	0.07420
Non-Hispanic Black	0.07012	0.06209	0.2588	-0.05160	0.1918
Hispanic	0.06593	0.08944	0.4611	-0.1094	0.2413
Non-Hispanic White	reference	n/a n/a	n/a		n/a.
Education					
College or >	-0.1646	0.06820	0.0158	-0.2983	-0.03090
High School Diploma	-0.01912	0.06665	0.7742	-0.1498	0.1116
Less than High School Diploma	-0.07235	0.07528	0.3366	-0.2200	0.07529
Unknown/Declined	reference	n/a n/a	n/a		n/a.
Insurance					
Private	0.2134	0.05612	0.0001	0.1034	0.3234
Medicare and Medicaid	0.03459	0.05765	0.5486	-0.07842	0.1476
Medicaid	0.3912	0.06811	<.0001	0.2577	0.5247
Medicaid	reference	n/a n/a	n/a		n/a.
English is Primary Language	-0.1599	0.06505	0.0140	-0.2874	-0.03232
History of Hypertension	0.2365	0.05985	<.0001	0.1191	0.3538
History of Coronary Heart Disease	-0.03921	0.04940	0.4274	-0.1361	0.05764

eTable 14: Full models for association between ZIP-level substance abuse resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	-0.03705	0.05766	0.5205	-0.1501	0.07598
History of Osteoarthritis	-0.1499	0.04010	0.0002	-0.2285	-0.07134
Charlson Comorbidity Score	0.01588	0.008146	0.0513	-0.00009	0.03185
Clinic Visits	0.006502	0.002846	0.0224	0.000922	0.01208
Clinic Connectedness					
Connected to specific physician	-0.08553	0.05430	0.1153	-0.1920	0.02092
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.3470	0.1270	0.0063	0.09804	0.5959
Lives in Area with Low Physical Food Access	-0.07748	0.06097	0.2039	-0.1970	0.04205
Percentage of Area Living in Group Quarters	-0.00001	0.000060	0.8418	-0.00013	0.000106
Lives in Area with Low Vehicle Access	0.04455	0.04429	0.3145	-0.04228	0.1314
ZIP-level Unemployment Rate	0.03710	0.01932	0.0549	-0.00078	0.07499
ZIP-level Median Household Income	1.636E-6	Unable to estimate	Unable to estimate	Unable to estimate	Unable to estimate
ZIP-level Poverty Rate	-0.00359	0.005890	0.5418	-0.01514	0.007953
ZIP-level Segregation	-0.00001	0.001802	0.9950	-0.00354	0.003522

eTable 15: Full models for association between ZIP-level mental health resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	7.0641	0.3371	<.0001	6.4033	7.7250
ZIP-level mental health resources	-0.00348	0.01130	0.7582	-0.02564	0.01868
ZIP-level afterschool resources	0.01159	0.006992	0.0974	-0.00212	0.02530
Age, years	-0.01058	0.001940	<.0001	-0.01438	-0.00678
Female	-0.1382	0.03843	0.0003	-0.2135	-0.06283
Race/ethnicity					
Asian/Multi/Other	-0.08415	0.08130	0.3007	-0.2435	0.07522
Non-Hispanic Black	0.07084	0.06217	0.2545	-0.05103	0.1927
Hispanic	0.06543	0.08946	0.4646	-0.1099	0.2408
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1647	0.06820	0.0158	-0.2984	-0.03095
High School Diploma	-0.01936	0.06665	0.7715	-0.1500	0.1113
Less than High School Diploma	-0.07325	0.07536	0.3312	-0.2210	0.07454
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	0.2135	0.05612	0.0001	0.1035	0.3235
Medicare and Medicaid	0.03499	0.05767	0.5440	-0.07805	0.1480
Medicaid	0.3913	0.06810	<.0001	0.2578	0.5248
Medicaid	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.1597	0.06502	0.0141	-0.2871	-0.03218
History of Hypertension	0.2365	0.05985	<.0001	0.1191	0.3538
History of Coronary Heart Disease	-0.03931	0.04940	0.4262	-0.1362	0.05753
History of Depression	-0.03699	0.05766	0.5212	-0.1500	0.07604

eTable 15: Full models for association between ZIP-level mental health resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.1498	0.04009	0.0002	-0.2284	-0.07123
Charlson Comorbidity Score	0.01585	0.008146	0.0518	-0.00012	0.03182
Clinic Visits	0.006518	0.002846	0.0220	0.000939	0.01210
Clinic Connectedness					
Connected to specific physician	-0.08559	0.05429	0.1150	-0.1920	0.02085
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.3477	0.1268	0.0061	0.09914	0.5962
Lives in Area with Low Physical Food Access	-0.07867	0.06091	0.1966	-0.1981	0.04074
Percentage of Area Living in Group Quarters	-0.00001	0.000060	0.8517	-0.00013	0.000107
Lives in Area with Low Vehicle Access	0.04534	0.04440	0.3072	-0.04169	0.1324
ZIP-level Unemployment Rate	0.03660	0.01940	0.0592	-0.00143	0.07462
ZIP-level Median Household Income	1.599E-6	Unable to estimate	Unable to estimate	Unable to estimate	Unable to estimate
ZIP-level Poverty Rate	-0.00359	0.005889	0.5423	-0.01513	0.007956
ZIP-level Segregation	-0.00002	0.001802	0.9931	-0.00355	0.003517

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	118.75	2.4411	<.0001	113.96	123.54
ZIP-level food resources	-0.08047	0.03550	0.0262	-0.1511	-0.00980
ZIP-level afterschool resources	0.06047	0.03336	0.0730	-0.00574	0.1267

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Age, years	0.1657	0.005420	<.0001	0.1550	0.1763
Female	-5.2802	0.1186	<.0001	-5.5126	-5.0477
Race/ethnicity					
Asian/Multi/Other	-2.6721	0.2363	<.0001	-3.1353	-2.2089
Non-Hispanic Black	0.6111	0.2706	0.0239	0.08082	1.1415
Hispanic	-0.7475	0.2728	0.0061	-1.2822	-0.2129
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.02240	0.1940	0.9080	-0.4026	0.3577
High School Diploma	0.4658	0.2125	0.0284	0.04932	0.8823
Less than High School Diploma	0.9903	0.2550	0.0001	0.4905	1.4901
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	-4.3672	2.1456	0.0418	-8.5725	-0.1618
Medicare and Medicaid	-4.2024	2.1674	0.0525	-8.4505	0.04573
Medicaid	-4.6349	2.1479	0.0309	-8.8449	-0.4248
Medicaid	-2.2777	2.1596	0.2916	-6.5105	1.9551
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.9827	0.2700	0.0003	0.4536	1.5119
History of Depression	-0.1126	0.2130	0.5970	-0.5301	0.3048
History of Osteoarthritis	0.5132	0.1754	0.0034	0.1695	0.8570
Charlson Comorbidity Score	0.1840	0.04369	<.0001	0.09834	0.2696
Clinic Visits	-0.05715	0.01445	<.0001	-0.08548	-0.02882
Clinic Connectedness					
Connected to specific physician	-0.6938	0.1282	<.0001	-0.9450	-0.4425

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	-0.4004	0.3700	0.2793	-1.1261	0.3254
Lives in Area with Low Physical Food Access	0.2289	0.1896	0.2274	-0.1429	0.6006
Percentage of Area Living in Group Quarters	-0.00031	0.000146	0.0348	-0.00060	-0.00002
Lives in Area with Low Vehicle Access	-0.00646	0.1455	0.9646	-0.2917	0.2788
ZIP-level Unemployment Rate	0.2795	0.07224	0.0001	0.1373	0.4218
ZIP-level Median Household Income	-0.00002	3.286E-6	<.0001	-0.00002	-9.76E-6
ZIP-level Poverty Rate	-0.02364	0.02254	0.2968	-0.06835	0.02108
ZIP-level Segregation	0.01658	0.006771	0.0154	0.003208	0.02995

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3-4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			7-8
Study design	4	Present key elements of study design early in the paper	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-10
Bias	9	Describe any efforts to address potential sources of bias	10-13
Study size	10	Explain how the study size was arrived at	13
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10-13
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10-13
		(b) Describe any methods used to examine subgroups and interactions	10-13, technical appendix
		(c) Explain how missing data were addressed	10-13
		(d) If applicable, describe analytical methods taking account of sampling strategy	10-13
		(e) Describe any sensitivity analyses	10-13

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	13
		(b) Give reasons for non-participation at each stage	13
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13-14, table 1, etables 2-3
		(b) Indicate number of participants with missing data for each variable of interest	Etables 2-3
Outcome data	15*	Report numbers of outcome events or summary measures	14-15
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-15
		(b) Report category boundaries when continuous variables were categorized	n/a
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14-16, eappendix
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18-19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Association Between Access to Social Service Resources and Cardiometabolic Risk Factors: A Machine Learning and Multi-Level Modeling Analysis

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Keywords:	SOCIAL MEDICINE, PRIMARY CARE, Hypertension < CARDIOLOGY, DIABETES & ENDOCRINOLOGY, Cardiac Epidemiology < CARDIOLOGY

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Manuscripts

1
2
3 **Association Between Access to Social Service Resources and Cardiometabolic**
4
5 **Risk Factors: A Machine Learning and Multi-Level Modeling Analysis**
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39
40
41 Key Words: cardiovascular disease, food insecurity, health disparities,
42
43 socioeconomic status
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3 **Objectives:** Interest in linking patients with unmet social needs to area-level
4 resources, such as food pantries and employment centers in one's ZIP code, is
5 growing. However, whether the presence of these resources is associated with
6 better health outcomes is unclear. We sought to determine if area-level resources,
7 defined as organizations that assist individuals with meeting health-related social
8 needs, are associated with lower levels of cardiometabolic risk factors.
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17 **Design:** Cross-sectional.

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20 **Setting:** Data were collected in a primary care network in eastern Massachusetts in
21 2015.
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24 **Participants and Primary and Secondary Outcome Measures:** 123,355

25 participants were included. The primary outcome was body mass index (BMI). The
26 secondary outcomes were systolic blood pressure (SBP), low density lipoprotein
27 cholesterol (LDL), and hemoglobin A1c (HbA1c). All participants were included in
28 BMI analyses. Participants with hypertension were included in SBP analyses.
29 Participants with an indication for cholesterol lowering were included in LDL
30 analyses, and participants with diabetes mellitus were included in HbA1c analyses.
31 We used a random forest-based machine-learning algorithm to identify types of
32 resources associated with study outcomes. We then tested the association of ZIP-
33 level selected resource types (three for BMI, two each for SBP and HbA1c analyses,
34 and one for LDL analyses) with these outcomes, using multi-level models to account
35 for individual-level, clinic-level, and other area-level factors.
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52 **Results:** Resources associated with lower BMI included more food resources (-0.08
53 kg/m² per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m²),
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3 employment resources (-0.05 kg/m², 95%CI -0.11 to -0.002 kg/m²), and nutrition
4
5 resources (-0.07 kg/m², 95%CI -0.13 to -0.01 kg/m²). No area resources were
6
7 associated with differences in SBP, LDL, or HbA1c.
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10 **Conclusions:** Access to specific local resources is associated with better BMI. Efforts
11
12 to link patients to area resources, and to improve the resources landscape within
13
14 communities, may help reduce BMI and improve population health.
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Strengths and Limitations of the Study

- Strength: Extensive individual and area-level data
- Strength: Innovative machine learning methods to overcome issues of collinearity and avoid multiple testing
- Strength: Use hierarchical linear modeling to account for data structure
- Limitation: Cross-sectional study
- Limitation: No information on use of resources

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3 Cardiometabolic disease remains the most common cause of morbidity and
4 mortality in the U.S.¹ Though better control of cardiometabolic risk factors could
5 substantially reduce this morbidity and mortality, individuals with low
6 socioeconomic status (SES) are less likely to achieve recommended goals.² Among
7 the reasons for this are patient-reported health-related social needs, including food
8 insecurity, housing instability, and lack of transportation. These health-related
9 social needs have been associated with higher levels of important cardiometabolic
10 risk factors including increased body mass index (BMI), systolic blood pressure
11 (SBP), low density lipoprotein cholesterol (LDL), and hemoglobin A1c (HbA1c), even
12 after adjusting for factors like race/ethnicity, income, and education.³⁻⁸ Proposed
13 mechanisms linking health-related social needs to cardiometabolic risk factors
14 including reduced dietary quality, cost-related medication underuse, reduced
15 cognitive 'bandwidth' to attend to health, and disruptions in clinical care.⁹⁻¹¹

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36 Healthcare systems are increasingly interested in working with community partners
37 to help link their patients to local resources, such as food pantries or housing
38 agencies, to help meet health-related social needs.¹²⁻¹⁶ This approach is exemplified
39 by the Accountable Health Communities initiative from the Centers for Medicare &
40 Medicaid Services, which involves screening for adverse social circumstances and
41 linking those who screen positive to community resources.¹⁷ However, there remain
42 significant gaps in knowledge regarding such approaches. Critically, healthcare
43 systems need to know which organizations to partner with, and potentially what
44 types of resources to invest in.¹⁸ The specific resources that best address a

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3 particular health-related need may not be straightforward. For example, a food
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5 pantry could help alleviate food insecurity, but so could employment.
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10 To help address these issues, and inform further interventions, we sought to study
11
12 associations between area resources and cardiometabolic risk factors in a large
13
14 primary care network. Our goal was to understand which resource types were
15
16 associated with improved levels of BMI, SBP, LDL, and HbA1c, and to determine
17
18 whether area resources had stronger associations with cardiometabolic risk factors
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20 for conditions that are less amenable to clinical management.
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26 **Methods**

27 *Setting and Study Sample*

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29 Data for this study came from two primary sources: an asset mapping of community
30
31 resources, and electronic health records. The asset mapping came from the
32
33 HelpSteps database, a comprehensive asset mapping of area resources in eastern
34
35 Massachusetts.¹⁹ The clinical records came from a primary care network in eastern
36
37 Massachusetts, a network of 18 primary care practices, including hospital-based,
38
39 academic, and community health center sites. All adult (age ≥ 18 years) primary
40
41 care patients seen between January 1, 2012 and December 31, 2015 were included.
42
43 Data were current on December 31, 2015. The most recent patient address was
44
45 geocoded for the study. Patients without available addresses were excluded—prior
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47 work has shown that only 0.15% of patients in this cohort could not be geocoded.²⁰
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3 The Partners Healthcare Human Research Committee exempted this analysis of
4 secondary data without patient contact from IRB review.
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10 *Patient and Public Involvement*

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12 The study research question was developed in reference to patient priorities
13 regarding the incorporation of neighborhood factors that promote health into
14 population health management. Patients were not involved in the design of the
15 study or in recruitment. We plan to disseminate study results via open-access
16 publication.
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26 *Area Resources*

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28 HelpSteps (www.helpsteps.com) is a web and mobile screening and referral system
29 for social needs. Originally launched in 2010, the system uses a database of social
30 services throughout the greater Boston area to connect families to appropriate
31 services. The database is maintained in collaboration between Boston Children's
32 Hospital and the Mayor's Health Line at the Boston Public Health Commission.
33
34 Every agency is contacted at least once per year to maintain the accuracy of the data
35 and to grow the database. HelpSteps contains information on area resources across
36 16 non-mutually exclusive domains: health, housing, food employment, violence,
37 safety, substance abuse, mental health, education, parenting, nutrition, after school,
38 sexual health, transportation, diabetes, and care transitions. An example of
39 organizations that would be in the food domain are food pantries. The employment
40 domain would consist of job placement or job training services. And the nutrition
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3 domain would include organizations that provide food counseling. Agencies
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5 providing multiple resources could be included in more than one domain. Because
6
7 individual-level data for this study came from 2015, we used information from
8
9 HelpSteps that was current as of 2015. For this study, 'area resources' are defined as
10
11 the number of organizations found in the HelpSteps database providing assistance
12
13 for a given domain and within a given geographic area.
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17 After geocoding the addresses for both individuals and the area resource
18
19 organization, we created counts, for each individual, of how many resources for each
20
21 domain were within the same geographic area as they were. We did this at 4
22
23 geographic levels in roughly increasing order of size: census tract (using U.S. Census
24
25 2010 boundaries), ZIP code tabulation area (which we refer to throughout this
26
27 paper as 'ZIP' level, owing to common use of the term, again using U.S. Census 2010
28
29 boundaries), 'neighborhood' (e.g. Allston, Roxbury, a designation based on Boston
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31 city planning that may better capture actual movement patterns), and county.
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38 *Clinical Outcomes*

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40 To assess clinical outcomes, we calculated the mean of all values recorded in 2015
41
42 from individual's electronic health record for the following measurements: body
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44 mass index (in kg/m²), systolic blood pressure (in mm Hg), low-density lipoprotein
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46 cholesterol (in mg/dL) and HbA1c (%). All values were obtained in the process of
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48 usual care.
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54 *Covariates*

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3 To account for possible confounding of the association between area resources and
4 health outcomes, we collected the following variables from the electronic health
5 record: age (years), gender (male or female), race/ethnicity (non-Hispanic white,
6 non-Hispanic black, Hispanic, or Asian/other/multi), education (less than high
7 school diploma, high school diploma [including GED], or greater than high school
8 diploma), insurance (commercial, Medicare, Medicaid [including dual-eligibles], and
9 uninsured/self-pay), number of clinic visits in 2015, primary language (English vs.
10 other), connectedness to their primary care clinic using previously validated
11 algorithm²¹, and comorbidity (Charlson comorbidity score, and individual indicators
12 of depression, hypertension, coronary heart disease, osteoarthritis, and diabetes).
13 To account for area-level differences from factors other than resources, we used
14 data from the U.S. Census' American Community Survey (5-year estimates 2010-
15 2015) and the USDA's Food Access Research Atlas: median household income,
16 percent living in poverty, 'food desert' status [low-income, low food access census
17 tract at 1/2 mile in urban areas and 10 miles in rural areas], unemployment rate,
18 proportion of the area population living in group quarters (e.g., those living in a
19 nursing facility unlikely to be exposed to area-level conditions), vehicle access, and
20 housing segregation.^{22,23}

21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 *Statistical analysis*

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50 In this study, we wanted to evaluate the relationship between many resources types
51 and cardiometabolic risk factors. A secondary goal of our study was to help
52 understand the relationship that specific geographic levels and resource types had
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3 with clinical outcomes. Because the nested structure of our data violate the
4
5 statistical independence assumption that underlies parametric, regression-based
6
7 variable selection approaches (such as forward, backward, or step-wise selection),
8
9 and to avoid multiple hypothesis testing that may lead to the identification of
10
11 spurious associations, we employed a non-parametric machine learning technique
12
13 called variable selecting using random forest (VSURF) to screen through variables in
14
15 the derivation set.^{24,25} This was done using a derivation dataset, which consisted of a
16
17 random partition of the entire dataset. Finally, we used multi-level modeling in the
18
19 test set (not used in the derivation stage) to test a small number of candidate
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21 variables identified by VSURF as being most important to explaining variations in
22
23 the derivation set. VSURF is described in more detail in the technical appendix and
24
25 eFigure 1.
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34 Multi-level modeling

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36 In the test dataset, we fit multi-level linear mixed models to test the association
37
38 between variables identified in the VSURF step and the outcome of interest. The BMI
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40 model included all study participants. The SBP model included those with a
41
42 diagnosis of hypertension. The LDL model included those with common diagnoses
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44 (hypertension, diabetes, coronary heart disease, cerebrovascular disease, congestive
45
46 heart failure) where LDL lowering is most beneficial. The HbA1c models included
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48 those with a diagnosis of diabetes. The models used fixed effects to adjust for age,
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50 gender, race/ethnicity, education, insurance, number of clinic visits, language, clinic
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52 connectedness, comorbidity, and census tract level median household income,
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3 poverty rates, 'food desert' status, unemployment, numbers living in group quarters,
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5 vehicle access, and segregation. To account for clustering within practices, we
6
7 included a practice-level random effects term. To account for area-level clustering,
8
9 we used a ZIP-level random effects term. These were fit as crossed effects models
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11 (i.e., we did not nest practices within ZIP codes) to allow for the fact that patients
12
13 are often seen in practices outside of their ZIP code of residence.
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19 Falsification tests

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21 To reduce the possibility that observed associations due to other unmeasured
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23 characteristics of the area, rather than the specific area resource tested, we also
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25 conducted falsification analyses. To do this, we used the same modeling approach as
26
27 above, but tested for the association between area after school resources for
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29 children and the outcome of interest. Our reasoning was that, since there was
30
31 unlikely to be any direct effect of afterschool resources for children on adult body
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33 mass index, any observed association would reflect unmeasured area-
34
35 characteristics not appropriately adjusted for in our model (such as high levels of
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37 civic engagement or community organization, or other beneficial resources).
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45 Variations in clinical management

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47 To help explore whether variations in the intensity of clinical management could
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49 explain whether community resources were associated with health outcomes, we
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51 also used the above modeling approach to test whether area resources were
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53 associated with SBP in those *without* a diagnosis of hypertension. The primary care
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3 network in the study has quality improvement program that emphasize the
4 importance of SBP, LDL, and HbA1c control in appropriate clinical populations.
5
6 Since BMI (in any population) and SBP control in those without a diagnosis of
7
8 hypertension are not included in these programs, we reasoned that area resources
9
10 may be more important when clinicians are not intensively attempting to impact an
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12 outcome. We focused on BMI and systolic blood pressure among those *without*
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14 hypertension for this because BMI and SBP are routinely measured at all practice
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16 visits for all patients.
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24 Because of its mechanistically plausible relationship with BMI, we used the
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26 association between ZIP-level food resources and BMI as the primary outcome, with
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28 secondary analyses being the associations between other VSURF selected area
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30 resources and clinical outcomes.
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36 Robustness checks

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41 In addition to the main analyses, we conducted a series of robustness checks that
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43 examined whether different specifications of resources in the area (e.g. resources
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45 per capita or resources per capita living in poverty) or different functional forms
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47 (e.g. including polynomial terms or using splines) would alter the observed
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49 associations between area-level resources and outcomes. We also conducted
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51 analyses restricted to those with indicators of lower socioeconomic status (high
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53 school diploma or lower educational attainment, living in a ZIP where > 15% of
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3 individuals are in poverty) to ensure the results were applicable to those most likely
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5 to utilize the resources studied.
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10 A p-value of < 0.05 was taken to indicate statistical significance. Analyses were
11
12 conducted in SAS Version 9.4 (Cary, NC), Stata 14 (College Station, TX), and R
13
14 version 3.3.4 (Vienna, Austria).
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19 **Results**

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21 Overall, 123,355 participants were included in the study. All participants were
22
23 eligible for the BMI analyses. Based on inclusion criteria, 43,509 were included in
24
25 the hypertension analyses, 46,940 were included in the LDL analyses, and 13,127
26
27 were included in the diabetes analyses. Demographic characteristics of the overall
28
29 sample are presented in Table 1. Demographic characteristics of the samples used in
30
31 the hypertension, LDL cholesterol, and diabetes analyses are presented in eTables 1-
32
33 3. Overall, the mean age was 52.4 (SD 16.9) years, the sample was 41.5% male,
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35 82.1% non-Hispanic white, 5.8% non-Hispanic black, and 6.5% Hispanic. The
36
37 median number of years participants were followed in our network was 9
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39 (intraquartile range (IQR): 3, 10), and the median number change of address per
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41 year followed was 0.1 (IQR 0.1, 0.25), suggesting that participants resided at their
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43 current address for the majority of their time in our network.
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52 In general, individuals living in areas with more resources were had lower
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54 educational attainment and higher rates of Medicaid insurance coverage (eTable 4).
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3 Maps depicting the distribution of the resources are presented in Figure 1 and
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5 eFigures 2-3.
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10 The mean BMI in the sample was 27.8 (SD 6.2) kg/m². In the hypertension analyses,
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12 the mean BP was 131.6 (SD 15.8) mmHg. In the LDL analyses, the mean LDL was
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14 102.9 (SD 39.8) mg/dL, and in the diabetes analyses the mean HbA1c was 7.1 (SD
15
16 1.5)%.
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22 Among geographic levels assessed, all resources selected were at the ZIP level
23
24 (Table 2). For the BMI analyses, the selected resources were ZIP level food
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26 resources, ZIP level employment resources, and ZIP level nutrition resources. For
27
28 hypertension analyses, the selected resources were ZIP housing and ZIP nutrition
29
30 resources. For LDL analyses, the only selected resource was ZIP nutrition resources.
31
32 For diabetes analyses, the selected resources were ZIP mental health and ZIP
33
34 substance use resources.
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41 For the BMI analyses, we tested the association between selected resources and
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43 BMI, adjusting for the factors described in the statistical analysis section, and
44
45 accounting for clustering at the clinic and ZIP level with multi-level linear mixed
46
47 models. We found that resources associated with lower BMI included more food
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49 resources (-0.08 kg/m² per additional resource, 95% Confidence Interval[CI] -0.13
50
51 to -0.03 kg/m², p= .001), employment resources (-0.05 kg/m², 95%CI -0.11 to -0.002
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53 kg/m², p=.04), and nutrition resources (-0.07 kg/m², 95%CI -0.13 to -0.01 kg/m²,
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3 p=.02) (full models for these and all robustness checks in eAppendix tables 5-16).
4
5 Table 3 compares mean BMI and obesity prevalence at selected numbers of
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7 resources, adjusted for the other factors in the model. For example, the mean BMI in
8
9 neighborhoods with the median (0) number of food resources was 27.8 kg/m²,
10
11 while the mean BMI in neighborhoods in the 75th percentile (3 resources) was 27.5
12
13 kg/m², and the 90th percentile (8 resources) was 27.1 kg/m². Falsification tests
14
15 found the expected lack of association between afterschool resources and BMI
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17 (p=.67).
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24 Robustness checks found that our results did not vary substantially with other
25
26 specifications of area-level resources (eTables 5-7).
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31 In the hypertension analyses, neither housing resources (-0.05 mm Hg per
32
33 additional resource, 95%CI -0.16 to 0.06 mm Hg, p=.41) nor nutrition resources
34
35 (0.01 mm Hg, 95%CI -0.13 to 0.16 mm Hg, p=.87) were associated with systolic
36
37 blood pressure after adjustment for individual level and area level characteristics. In
38
39 LDL analyses, nutrition resources (0.10 mg/dL per additional resource, 95%CI -0.36
40
41 to 0.55 mg/dL, p=.67) were not associated with LDL cholesterol in adjusted models.
42
43 In diabetes analyses, neither substance abuse resources (-0.003% per additional
44
45 resource, 95%CI -0.03 to 0.02%, p=.86) nor mental health resources were
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47 associated with HbA1c (-0.003 %, 95%CI -0.03 to 0.02%, p=.76).
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3 In analyses looking at systolic blood pressure among those without a diagnosis of
4 hypertension (i.e., those with no reason for clinical management of blood pressure),
5
6 food resources were associated with lower systolic blood pressure in linear mixed
7
8 models adjusted for the same factors as above (-0.08 mm Hg per additional
9
10 resource, 95%CI -0.15 to -0.01 mm Hg, p=.03). Mean systolic blood pressure was
11
12 approximately 1 mm Hg lower at the 95th percentile (118.9 mm Hg) of food
13
14 resources compared with the 50th percentile (119.8 mm Hg).
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22 Full models for all analyses are presented in eTables 8-16.
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26 **Discussion**

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29 This study assessed the relationship among area resources and cardiometabolic risk
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31 factors. We found that increasing numbers of food, employment, and nutrition
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33 resources was associated with lower BMI, and lower systolic blood pressure among
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35 those without hypertension. The magnitude of the difference was meaningful at the
36
37 population level, as the 0.7 kg/m² difference in BMI between individuals in a well-
38
39 resourced versus poorly resourced ZIP is similar to the 0.6 increase kg/m² in BMI in
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41 the overall U.S. population from 2006 to 2016.²⁶
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48 Conversely, we found that area resources were not associated with systolic blood
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50 pressure among those with hypertension, LDL cholesterol among those with an
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52 indication for LDL lowering, or hemoglobin A1c among those with diabetes. This
53
54 suggests that the relationship between area resources and cardiometabolic risk
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3 factors may vary based on whether these factors are targets of intensive clinical
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5 management.
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10 This study enhances our knowledge regarding the association of area-level factors
11 and cardiometabolic risk factors. Prior studies have consistently found that adverse
12 area-level factors, such as poverty, are associated with increased cardiometabolic
13 risk, even when adjusting for individual-level factors, such as income.^{2,27-29}
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19 However, we did not know whether the presence of area resources that might
20 plausibly support health, such as food and nutrition resources, would be associated
21 with lower cardiometabolic risk.
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29 The positive and negative associations between community resources and
30 cardiometabolic risk factors may have important public health implications. The
31 association between increased area resources and lower BMI suggests that efforts to
32 help link patients to community resources, and to help improve the resources
33 landscape within communities, may be a successful strategy for improving
34 population health, particularly for risk factors such as BMI where clinical
35 management may not be prioritized.^{13,14,30} This is reinforced by the finding that SBP,
36 among those without hypertension, is lower in those living in areas with more
37 resources. Since SBP does not come under clinical management for those without
38 hypertension, this finding supports the potential for area resources to impact
39 population health, and is consistent with guidelines that recommend lifestyle, rather
40 than pharmacologic, approaches to pre-hypertension treatment.³¹ Future work in
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3 this area should investigate whether interventions that link individuals to area
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5 resources show clinical benefits.
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10 Our finding should be interpreted in light of several limitations. We did not have
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12 access to data regarding use of the resources. This means that we do not know
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14 whether individuals made use of the resources in their community. In light of this,
15
16 the association between ZIP-level resources and outcomes could be viewed
17
18 analogously to an 'encouragement design' intervention. This means that the
19
20 association estimated in this study is likely different than the association that would
21
22 be estimated if analyzing those who were known to use the resource. That
23
24 association is clearly of policy interest, and should be examined in future work.
25
26 While we adjusted for several individual-level and area-level socioeconomic status
27
28 indicators in order to capture the multidimensional nature of socioeconomic status
29
30 and, thus, reduce confounding, it is possible that residual confounding, owing to
31
32 unmeasured characteristics, exists, which would tend to reduce the observed
33
34 associations between area-resources and outcomes. Additional unmeasured
35
36 covariates that could affect the observed associations include local culture, and the
37
38 quality of the resources available. Devising methodology to determine the quality of
39
40 the services provided to help meet health-related social needs is pressing, and will
41
42 be an important direction for future investigation. Next, our study was cross-
43
44 sectional, and thus we cannot establish time-ordering between the exposure and the
45
46 cardiometabolic outcomes. However, we think it is less likely that lower BMI would
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48 drive individuals into areas with more resources than vice versa, as areas with
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3 higher resources tended to have other adverse features, such as lower income and
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5 higher poverty, which are likely more salient considerations for those choosing
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7 where to live. Finally, because of the relatively high residential stability within this
8
9 primary care population, we only examined the association between current area of
10
11 residence and the study outcomes. However, for those who do move, this could lead
12
13 to misclassification, which would tend to bias results to the null. These limitations
14
15 are balanced by several strengths. We had access to a detailed mapping of area
16
17 resources, along with detailed individual-level health information. Further, in
18
19 addition to the multi-level framework we used, the use of falsification tests
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21 demonstrated that unadjusted area-level factors are not likely to explain the
22
23 observed results.
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31 In summary, ZIP-level food, employment, and nutrition resources were associated
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33 with BMI differences that were clinically meaningfully and statistically significant.
34
35 Further, the association between area resources and cardiometabolic risk factors
36
37 differed based on the specific risk factor. Investing in area resources and linkage
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39 programs may be an important way to help reduce cardiometabolic risk for
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41 vulnerable individuals, especially for situations not under intensive clinical
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43 management.
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Competing Interest Statement: All authors declare they have nothing to disclose

Guarantor: Seth A. Berkowitz had full access to all of the data in the study and takes full responsibility for the work as a whole, including the study design, access to data, the integrity of the data, the accuracy of the data analysis, and the decision to submit and publish the manuscript.

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Table 1: Demographics of study sample

	N=123,355
	Mean (SD) or n (%)
Age	52.42 (16.89)
Male	51665 (41.9)
Race/ethnicity	
Asian/Multi/Other	6880 (5.6)
Non-Hispanic Black	7203 (5.8)
Hispanic	8039 (6.5)
Non-Hispanic White	101233 (82.1)
Education	
College or >	56302 (45.6)
High School Diploma	36572 (29.6)
Less than High School Diploma	18051 (14.6)
Unknown/Declined	12430 (10.1)
Insurance	
Private	75787 (61.4)
Medicare and Medicaid	8602 (7.0)
Medicaid	20934 (17.0)
Medicare	17911 (14.5)
Self-pay	121 (0.1)
English is Primary Language	112720 (91.4)
History of Hypertension	43509 (35.3)
History of Coronary Heart Disease	9275 (7.5)
History of Diabetes Mellitus	13127 (10.6)
History of Depression	10300 (8.3)
History of Osteoarthritis	23707 (19.2)
Charlson Comorbidity Score	1.72 (2.23)
Clinic Visits	6.57 (5.77)
Clinic Connectedness	
Connected to specific physician	80345 (65.1)
Connected to specific practice	34018 (27.6)
Other	8992 (7.3)
Lives in Urban Area	91095 (96.4)
ZIP-level Unemployment Rate, %	4.71 (1.60)
ZIP-level Median Household Income, \$	82309.16 (31758.79)
ZIP-level Poverty Rate, %	8.70 (6.72)
ZIP-level Segregation*	69.51 (21.05)
Body Mass Index, kg/m ²	27.84 (6.24)
Systolic Blood Pressure, mm Hg	124.36 (14.96)

LDL cholesterol, mg/dL	110.83 (39.95)
Hemoglobin A1c, %	5.94 (1.22)

*Segregation index is a dissimilarity measure of the extent to which groups other than non-Hispanic whites are distributed like non-Hispanic whites. 0 represents complete integration and 100 represents complete segregation.

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Table 2: Distribution of the Number of Resources in the Selected Resource Categories

BMI Analyses							
Resource*	Minimum	25 th Percentile	50 th Percentile	75 th Percentile	90 th Percentile	95 th Percentile	Maximum
Food	0	0	0	3	8	11	27
Employment	0	0	0	4	13	18	33
Nutrition	0	0	0	3	6	12	21
Hypertension Analyses							
Housing	0	0	0	2	8	8	23
Nutrition	0	0	0	3	6	12	21
LDL Analyses							
Nutrition	0	0	0	3	6	12	21
Diabetes Analyses							
Mental health	0	0	0	2	5	6	21
Substance use resources	0	0	1	2	5	6	23

*All resources assessed at ZIP level; table represents counts of each resource type

Table 3: Estimated BMI, in kg/m², by resource level

ZIP-level Food Resources	
50 th Percentile	27.78
75 th Percentile	27.53
90 th Percentile	27.11
95 th Percentile	26.85
ZIP-level Employment Resources	
50 th Percentile	27.78
75 th Percentile	27.56
90 th Percentile	27.07
95 th Percentile	26.80
ZIP-level Nutrition Resources	
50 th Percentile	27.75
75 th Percentile	27.54
90 th Percentile	27.32
95 th Percentile	26.89

Estimates created using least-squares means from fitted multi-level models. The models used fixed effects to adjust for age, gender, race/ethnicity, education, insurance, number of clinic visits, language, clinic connectedness, comorbidity, and census tract level median household income, poverty rates, 'food desert' status, unemployment, numbers living in group quarters, vehicle access, and segregation. To account for clustering within practices, we included a practice-level random effects term. To account for area-level clustering, we used a ZIP-level random effects term. These were fit as crossed effects models (i.e., we did not nest practices within ZIP codes) to allow for the fact that patients are often seen in practices outside of their ZIP code of residence.

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Figure 1: Food Resource Density by ZIP

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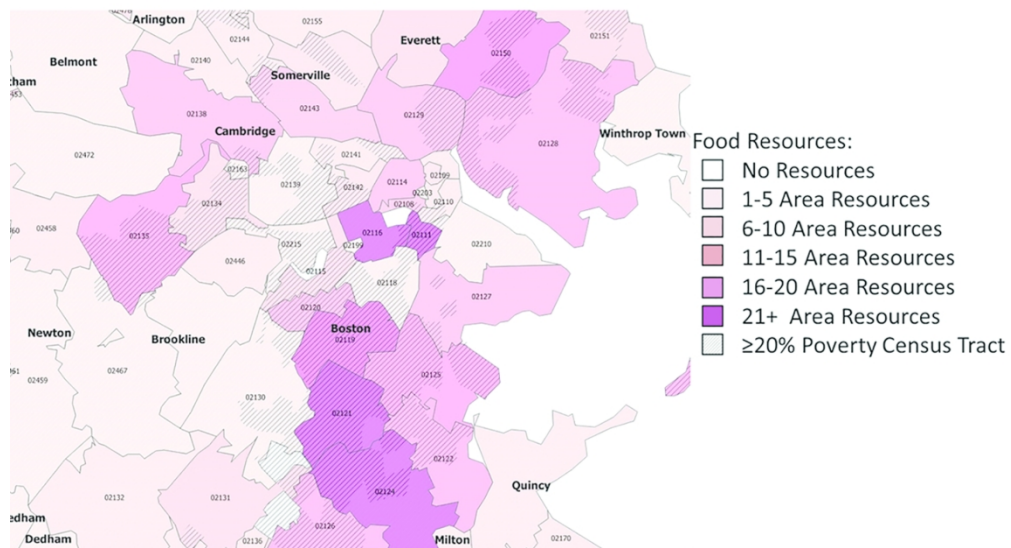


Figure 1

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eAppendix for Association Between Area Resources and Cardiometabolic Risk: A Machine Learning and Multi-Level Modeling Analysis

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Technical Appendix

VSURF

The foundation of the VSURF technique is the decision tree (eFigure 1).²¹ To construct a single decision tree, the procedure selects a random subset of variables from the total number of available variables, and selects a variable that best explains the variation in outcome of a bootstrap resample drawn from the derivation sample. For the next split, the variable that best explains the variation within each ‘branch’ of the tree created in the first split is selected. This process is continued until optimal separation is achieved. A ‘forest’ is grown by repeating this process 2000 times, each time randomly drawing a subset of variables and bootstrap resample of the derivation cohort. In the VSURF procedure, 50 forests of 2000 trees were grown in the initial ‘thresholding’ step, which focuses on removing irrelevant variables. Then, 25 forests of 2000 trees, using the remaining variables, were grown to select all variables associated with the response. Finally, 25 forests of 2000 trees were grown, selecting among the remaining variables to eliminate redundancy. After all three steps were completed, we selected up to the top three area resources, as indicated by variable importance factors in the final step, for hypothesis testing in the independent, ‘testing’ sample.

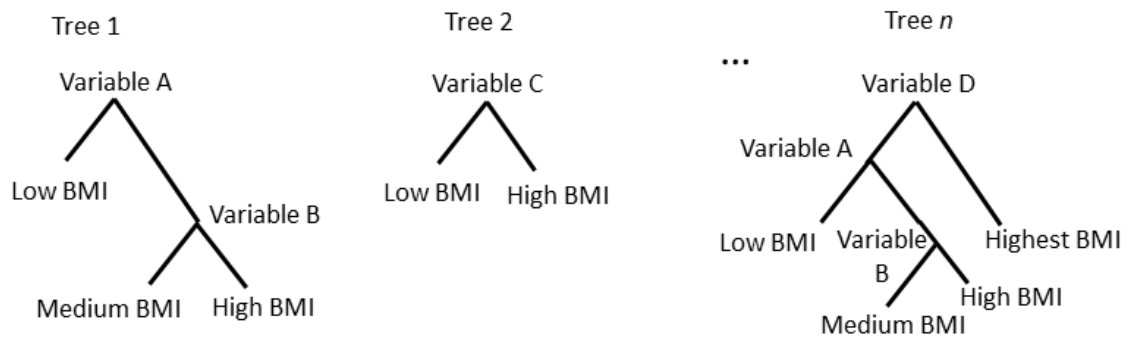
A major advantage of VSURF is that it directly addresses the correlation among variables, as the single best variable is selected at each split and thus the explanatory power is not divided amongst two or more related variables, as in linear regression. Secondly, VSURF allows one to screen through a number of candidate variables while preserving type I error rate, as statistical

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significance testing is not used in the selection of variables, unlike p-value-based selection algorithms.

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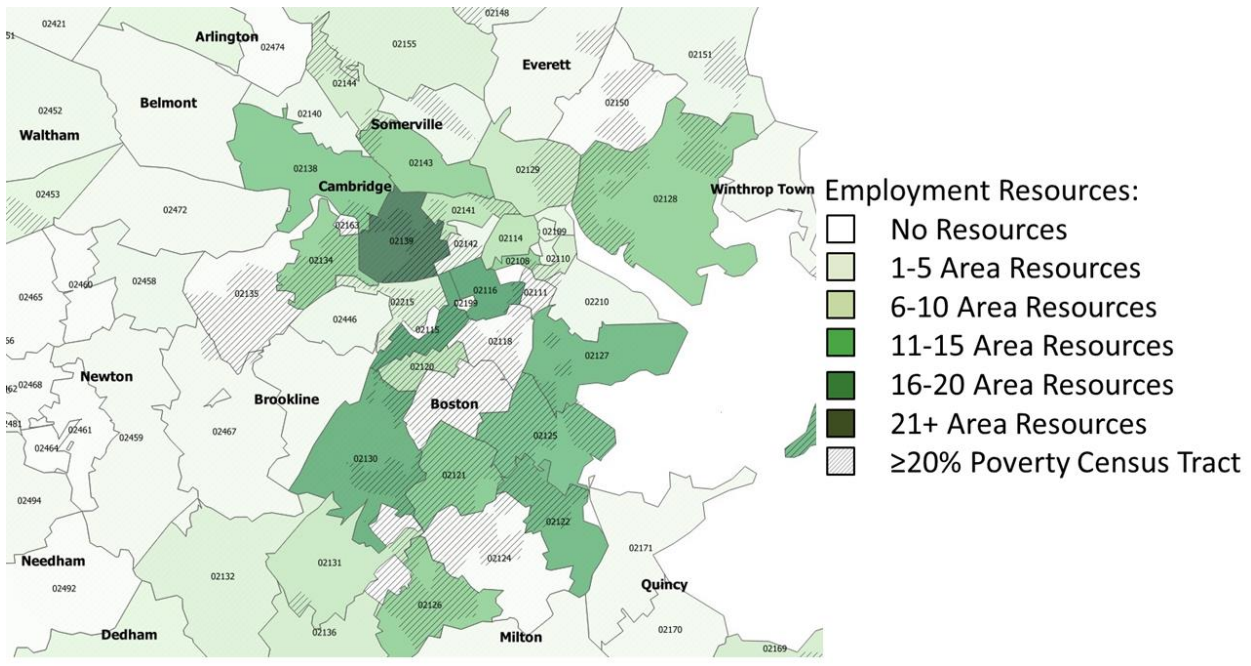
eFigure 1: Depiction of the Variable Selection Using Random Forest (VSURF) Method



From a random subset of variables and a bootstrap resample of individuals in the derivation cohort, a decision tree that optimally splits the sample is created. This process is repeated in a second bootstrap resample with a second randomly selected subset of variables, and so on until n trees ($n=2000$ in this study) are aggregated to create one forest. The forest-growing procedure is repeated 50 times. Then, using variable importance factors, which indicate the variables that are most useful in minimizing the error of predicted values in the 'out-of-bag' sample (those observations that, due to chance, were not selected in the bootstrap resample). After removing the least important variables, the entire process is repeated again, this time growing 25 forests of 2000 trees, in the 'interpretation' step, which focuses on selecting all variables associated with the response. Finally, to deal with correlations between variables, the process is repeated again, growing 25 more forests of 2000 trees, in the 'prediction' step, which focuses on removing redundancy in the final set of variables.

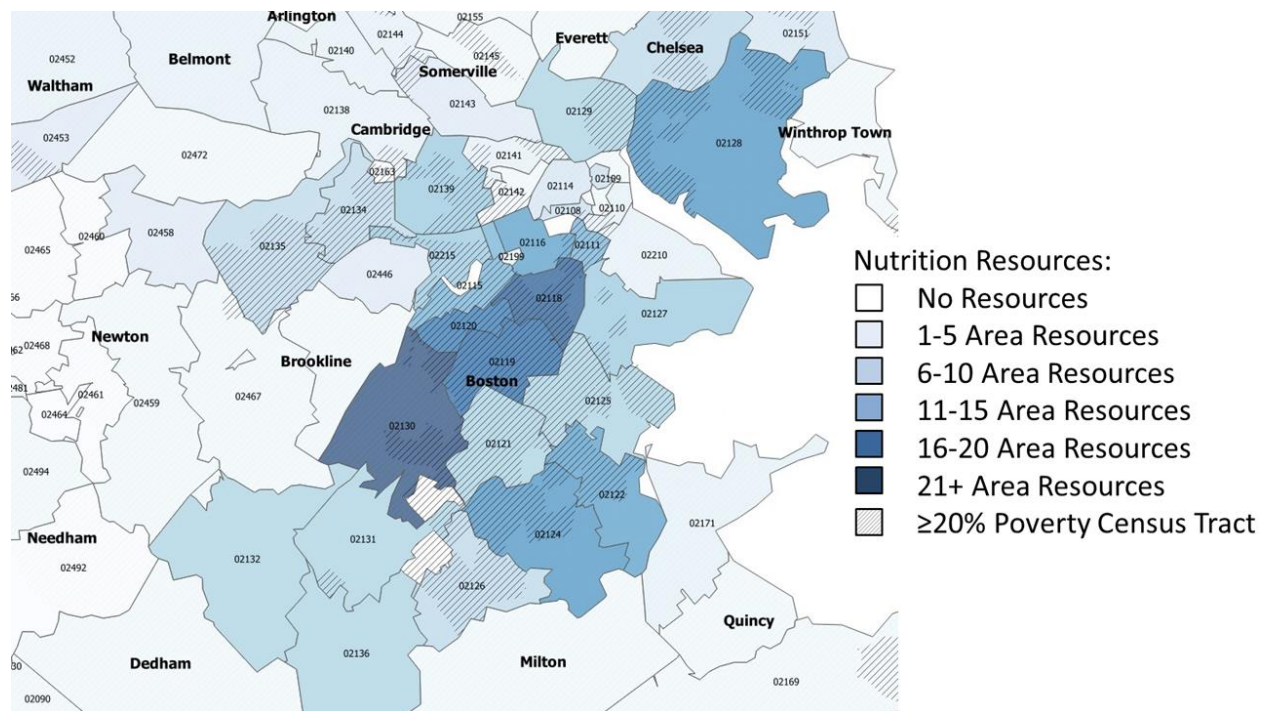
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eFigure 2: Employment Resources by ZIP



Review only

eFigure 3: Nutrition Resources by ZIP



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eTable 1: Demographics for Hypertension Study Sample

	N=43,509
	Mean (SD) or n (%)
Age	64.67 (14.05)
Male	21299 (49.0)
Race/ethnicity	
Asian/Multi/Other	1755 (4.0)
Non-Hispanic Black	3138 (7.2)
Hispanic	1983 (4.6)
Non-Hispanic White	36633 (84.2)
Education	
College or >	15660 (36.0)
High School Diploma	15900 (36.5)
Less than High School Diploma	7422 (17.1)
Unknown/Declined	4527 (10.4)
Insurance	
Private	17256 (39.7)
Medicare and Medicaid	6200 (14.2)
Medicaid	6292 (14.5)
Medicare	13756 (31.6)
Self-pay	5 (0.0)
English is Primary Language	39492 (90.8)
History of Coronary Heart Disease	8373 (19.2)
History of Diabetes Mellitus	11085 (25.5)
History of Depression	4745 (10.9)
History of Osteoarthritis	14931 (34.3)
Charlson Comorbidity Score	3.22 (2.57)
Clinic Visits	9.58 (6.77)
Clinic Connectedness	
Connected to specific physician	36233 (83.3)
Connected to specific practice	6978 (16.0)
Other	298 (0.7)
Lives in Urban Area	32075 (96.4)
ZIP-level Unemployment Rate, %	4.85 (1.63)
ZIP-level Median Household Income, \$	80247.61 (31190.75)
ZIP-level Poverty Rate, %	8.67 (6.63)
ZIP-level Segregation	69.19 (21.92)
Body Mass Index, kg/m ²	29.68 (6.40)
History of Obesity	19314 (45.2)
Systolic Blood Pressure, mm Hg	131.60 (15.75)

LDL cholesterol, mg/dL	102.73 (39.82)
Hemoglobin A1c, %	6.25 (1.34)

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eTable 2: Demographics for LDL Study Sample

	N=46940
	Mean (SD) or n (%)
Age	63.96 (14.33)
Male	22916 (48.8)
Race/ethnicity	
Asian/Multi/Other	1971 (4.2)
Non-Hispanic Black	3401 (7.2)
Hispanic	2285 (4.9)
Non-Hispanic White	39283 (83.7)
Education	
College or >	16940 (36.1)
High School Diploma	17032 (36.3)
Less than High School Diploma	8075 (17.2)
Unknown/Declined	4893 (10.4)
Insurance	
Private	18909 (40.3)
Medicare and Medicaid	6561 (14.0)
Medicaid	7169 (15.3)
Medicare	14296 (30.5)
Self-pay	5 (0.0)
English is Primary Language	42468 (90.5)
History of Hypertension	43509 (92.7)
History of Coronary Heart Disease	9275 (19.8)
History of Diabetes Mellitus	13127 (28.0)
History of Depression	5160 (11.0)
History of Osteoarthritis	15695 (33.4)
Charlson Comorbidity Score	3.14 (2.54)
Clinic Visits	9.46 (6.71)
Clinic Connectedness	
Connected to specific physician	38851 (82.8)
Connected to specific practice	7746 (16.5)
Other	343 (0.7)
Lives in Urban Area	34532 (96.4)
ZIP-level Unemployment Rate, %	4.86 (1.63)
ZIP-level Median Household Income, \$	80079.26 (31173.63)
ZIP-level Poverty Rate, %	8.72 (6.64)
ZIP-level Segregation	68.98 (21.98)
Body Mass Index, kg/m ²	29.63 (6.42)
History of Obesity	20611 (44.7)
Systolic Blood Pressure, mm Hg	130.88 (15.75)

LDL cholesterol, mg/dL	102.85 (39.81)
Hemoglobin A1c, %	6.28 (1.36)

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eTable 3: Demographics for Diabetes Study Sample

	N=13127
	Mean (SD) or n (%)
Age	64.12 (14.10)
Male	6722 (51.2)
Race/ethnicity	
Asian/Multi/Other	729 (5.6)
Non-Hispanic Black	1415 (10.8)
Hispanic	986 (7.5)
Non-Hispanic White	9995 (76.1)
Education	
College or >	3691 (28.1)
High School Diploma	5115 (39.0)
Less than High School Diploma	3085 (23.5)
Unknown/Declined	1236 (9.4)
Insurance	
Private	4247 (32.4)
Medicare and Medicaid	2609 (19.9)
Medicaid	2654 (20.2)
Medicare	3617 (27.6)
Self-pay	0 (0.0)
English is Primary Language	11138 (84.8)
History of Hypertension	11085 (84.4)
History of Coronary Heart Disease	3316 (25.3)
History of Diabetes Mellitus	13127 (100.0)
History of Depression	1685 (12.8)
History of Osteoarthritis	4605 (35.1)
Charlson Comorbidity Score	4.34 (2.94)
Clinic Visits	11.59 (7.52)
Clinic Connectedness	
Connected to specific physician	10778 (82.1)
Connected to specific practice	2234 (17.0)
Other	115 (0.9)
Lives in Urban Area	9467 (97.4)
ZIP-level Unemployment Rate, %	5.24 (1.67)
ZIP-level Median Household Income, \$	72660.30 (28239.05)
ZIP-level Poverty Rate, %	10.19 (6.83)
ZIP-level Segregation	63.62 (23.80)
Body Mass Index, kg/m ²	31.48 (6.85)
History of Obesity	7427 (57.7)
Systolic Blood Pressure, mm Hg	130.17 (16.09)

LDL cholesterol, mg/dL	89.25 (37.45)
Hemoglobin A1c, %	7.08 (1.52)

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eTable 4: Demographics of study sample by number of food resources in ZIP code tabulation area

	0 food resources	1 to 7 food resources	≥8 food resources	p
	N=65011	N=42794	N=13028	
	Mean (SD) or n (%)	Mean (SD) or n (%)	Mean (SD) or n (%)	
Age	53.93 (16.13)	51.05 (17.69)	47.95 (16.92)	<0.001
Male	28050 (43.1)	17330 (40.5)	5163 (39.6)	<0.001
Race/ethnicity				<0.001
Asian/Multi/Other	3559 (5.5)	2501 (5.8)	709 (5.4)	
Non-Hispanic Black	2553 (3.9)	2710 (6.3)	1605 (12.3)	
Hispanic	2306 (3.5)	2859 (6.7)	2707 (20.8)	
Non-Hispanic White	56593 (87.1)	34724 (81.1)	8007 (61.5)	
Education				<0.001
College or >	31782 (48.9)	18895 (44.2)	4837 (37.1)	
High School Diploma	18400 (28.3)	13355 (31.2)	3767 (28.9)	
Less than High School Diploma	7373 (11.3)	6762 (15.8)	3449 (26.5)	
Unknown/Declined	7456 (11.5)	3782 (8.8)	975 (7.5)	
Insurance				<0.001
Private	44051 (67.8)	24062 (56.2)	6600 (50.7)	
Medicare and Medicaid	3485 (5.4)	3551 (8.3)	1188 (9.1)	
Medicaid	7319 (11.3)	9011 (21.1)	4075 (31.3)	
Medicare	10128 (15.6)	6093 (14.2)	1149 (8.8)	
Self-pay	28 (0.0)	77 (0.2)	16 (0.1)	
English is Primary Language	61559 (94.7)	38982 (91.1)	9923 (76.2)	<0.001
History of Hypertension	22195 (34.1)	15367 (35.9)	4342 (33.3)	<0.001
History of Coronary Heart Disease	4663 (7.2)	3385 (7.9)	817 (6.3)	<0.001
History of Cerebrovascular Disease	1628 (2.5)	1148 (2.7)	316 (2.4)	0.114
History of Congestive Heart Failure	1941 (3.0)	1793 (4.2)	460 (3.5)	<0.001
History of Diabetes Mellitus	5735 (8.8)	4757 (11.1)	1735 (13.3)	<0.001
History of Depression	4598 (7.1)	4024 (9.4)	1377 (10.6)	<0.001
History of Osteoarthritis	12179 (18.7)	8386 (19.6)	2331 (17.9)	<0.001
Charlson Comorbidity Score	1.70 (2.17)	1.72 (2.28)	1.56 (2.15)	<0.001
Clinic Visits	5.93 (5.18)	7.14 (6.21)	7.19 (6.11)	<0.001
Clinic Connectedness				<0.001
Connected to specific physician	41292 (63.5)	28457 (66.5)	8593 (66.0)	
Connected to specific practice	14727 (22.7)	14337 (33.5)	4435 (34.0)	
Other	8992 (13.8)	0 (0.0)	0 (0.0)	
Lives in Urban Area	52165 (94.3)	29291 (99.4)	7118 (99.9)	<0.001
ZIP-level Unemployment Rate, %	4.27 (1.41)	4.89 (1.51)	5.82 (1.83)	<0.001
ZIP-level Median Household Income, \$	96937.11 (34242.61)	71648.83 (21514.21)	58606.22 (17651.59)	<0.001

ZIP-level Poverty Rate, %	4.91 (4.58)	11.12 (6.26)	15.94 (5.58)	<0.001
ZIP-level Segregation	80.59 (15.85)	65.17 (15.29)	39.16 (20.13)	<0.001
Body Mass Index, kg/m ²	27.64 (6.03)	27.82 (6.34)	28.30 (6.63)	<0.001
History of Obesity	18693 (30.1)	12765 (30.8)	4148 (33.2)	<0.001
Systolic Blood Pressure, mm Hg	124.47 (14.92)	124.27 (15.03)	123.44 (14.80)	<0.001
LDL cholesterol, mg/dL	112.17 (42.48)	109.92 (37.14)	108.83 (35.34)	<0.001
Hemoglobin A1c, %	5.86 (1.12)	5.98 (1.25)	6.13 (1.43)	<0.001

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Robustness checks (eTable 5-7)

Results from analyses, adjusted for the same factors as in main model presented in the manuscript, comparing the association of food resources and BMI with different specifications of ZIP-level food resources (count, count per capita, and count per capita living in poverty) show that the association between more area food resources and lower BMI is robust to different specifications of number of resources

eTable 5: Analyses comparing the association of food resources and BMI with different specifications of area-resources

Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), kg/m ² (main model from manuscript)	Estimated difference in BMI associated with 1 additional ZIP-level resource per 10000 people (95% CI), kg/m ²	Estimated difference in BMI associated with 1 additional ZIP-level resource per 10000 people living in poverty (95% CI), kg/m ²
-0.08 (-0.13 to -0.03)	-0.19 (-0.29 to -0.085)	-0.02 (-0.03 to -0.01)

Analyses, adjusted for the same factors as in main model presented in the manuscript, including a quadratic and/or cubic term, or restricted cubic splines, to represent the number of ZIP-level resources resulted in worse model fit by Akaike information criterion and Bayes information criterion, suggesting that a linear approximation of the relationship between ZIP-level resources and the modeled outcome is reasonable.

eTable 6: Model fit statistics from different specifications of ZIP-level food resources		
	Akaike information criterion (smaller represents better fit)	Bayes information criterion (smaller represents better fit)
Linear term only	468646.6	468640.6
Linear plus quadratic	468656.5	468650.5
Linear, quadratic, and cubic	468667.8	468661.8
Restricted cubic spline	468656.0	468650.0

Analyses, adjusted for the same factors as in main model presented in the manuscript, restricted to those with indicators of lower socioeconomic status show that the estimates for the association between additional ZIP-level food resources and BMI are slightly larger than in the overall population, which is consistent with the idea that these resources are beneficial for those with lower socioeconomic status

eTable 7: Analyses of association between ZIP-level food resources and body mass index, restricted to those with indicators of lower socioeconomic status

Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), kg/m ² (main model from manuscript)	Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), restricted to those with high school diploma or lower educational attainment, kg/m ²	Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), restricted to those living in ZIP with > 15% living in poverty, kg/m ²
-0.08 (-0.13 to -0.03)	-0.09 (-0.15 to -0.04)	-0.11 (-0.17 to -0.06)

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eTable 8: Full models for association between ZIP-level food resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.2196	1.1796	<.0001	25.9071	30.5320
ZIP-level food resources	-0.08429	0.02512	0.0010	-0.1340	-0.03460
ZIP-level afterschool resources	0.009484	0.02203	0.6674	-0.03404	0.05301
Age, years	-0.04950	0.002011	<.0001	-0.05344	-0.04556
Female	-1.3794	0.04395	<.0001	-1.4656	-1.2933
Race/ethnicity					
Asian/Multi/Other	-2.5117	0.09328	<.0001	-2.6945	-2.3288
Non-Hispanic Black	0.9600	0.09753	<.0001	0.7688	1.1511
Hispanic	0.7277	0.1081	<.0001	0.5157	0.9396
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2793	0.07082	<.0001	-0.4181	-0.1404
High School Diploma	0.09622	0.07549	0.2025	-0.05175	0.2442
Less than High School Diploma	0.3871	0.09117	<.0001	0.2084	0.5658
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1890	1.0208	0.8531	-1.8118	2.1898
Medicare and Medicaid	0.06964	1.0240	0.9458	-1.9374	2.0767
Medicaid	0.6961	1.0215	0.4956	-1.3061	2.6983
Medicaid	-0.4968	1.0230	0.6272	-2.5019	1.5083
Self-pay	reference	n/a	n/a	n/a	n/a
English is Primary Language	0.7128	0.09604	<.0001	0.5246	0.9011
History of Hypertension	2.7291	0.05550	<.0001	2.6203	2.8379
History of Coronary Heart Disease	-0.4141	0.08601	<.0001	-0.5827	-0.2455
History of Diabetes Mellitus	2.4217	0.07471	<.0001	2.2752	2.5681

eTable 8: Full models for association between ZIP-level food resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	0.5488	0.07350	<.0001	0.4048	0.6929
History of Osteoarthritis	1.3188	0.05467	<.0001	1.2116	1.4260
Charlson Comorbidity Score	0.06713	0.01268	<.0001	0.04227	0.09198
Clinic Visits	-0.00068	0.004383	0.8770	-0.00927	0.007911
Clinic Connectedness					
Connected to specific physician	0.3184	0.05024	<.0001	0.2200	0.4169
Connected to specific practice	reference	n/a	n/a	n/a	n/a
Lives in Urban Area	0.2640	0.1580	0.0949	-0.04583	0.5739
Lives in Area with Low Physical Food Access	0.09426	0.07794	0.2265	-0.05851	0.2470
Percentage of Area Living in Group Quarters	-0.00020	0.000060	0.0009	-0.00032	-0.00008
Lives in Area with Low Vehicle Access	0.1189	0.05577	0.0331	0.009564	0.2282
ZIP-level Unemployment Rate	0.2608	0.03829	<.0001	0.1855	0.3361
ZIP-level Median Household Income	-0.00001	1.936E-6	<.0001	-0.00002	-8.81E-6
ZIP-level Poverty Rate	-0.03254	0.01370	0.0183	-0.05952	-0.00555
ZIP-level Segregation	0.002536	0.003897	0.5158	-0.00514	0.01021

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.1779	1.1847	<.0001	25.8554	30.5004
ZIP-level employment resources	-0.05415	0.02624	0.0407	-0.1060	-0.00231

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
ZIP-level afterschool resources	0.01083	0.03215	0.7366	-0.05269	0.07436
Age, years	-0.04951	0.002011	<.0001	-0.05345	-0.04557
Female	-1.3795	0.04395	<.0001	-1.4656	-1.2933
Race/ethnicity					
Asian/Multi/Other	-2.5089	0.09330	<.0001	-2.6918	-2.3260
Non-Hispanic Black	0.9669	0.09755	<.0001	0.7757	1.1581
Hispanic	0.7300	0.1081	<.0001	0.5181	0.9420
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2787	0.07083	<.0001	-0.4175	-0.1399
High School Diploma	0.09646	0.07549	0.2013	-0.05150	0.2444
Less than High School Diploma	0.3880	0.09117	<.0001	0.2093	0.5667
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1930	1.0208	0.8500	-1.8078	2.1938
Medicare and Medicaid	0.07527	1.0240	0.9414	-1.9318	2.0823
Medicaid	0.7010	1.0215	0.4926	-1.3012	2.7032
Medicaid	-0.4922	1.0230	0.6304	-2.4973	1.5128
Self-pay	reference	n/a	n/a	n/a	n/a
English is Primary Language	0.7126	0.09604	<.0001	0.5243	0.9008
History of Hypertension	2.7296	0.05550	<.0001	2.6208	2.8383
History of Coronary Heart Disease	-0.4138	0.08601	<.0001	-0.5824	-0.2452
History of Diabetes Mellitus	2.4215	0.07471	<.0001	2.2751	2.5680
History of Depression	0.5493	0.07350	<.0001	0.4052	0.6933
History of Osteoarthritis	1.3190	0.05467	<.0001	1.2118	1.4261

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Charlson Comorbidity Score	0.06713	0.01268	<.0001	0.04227	0.09198
Clinic Visits	-0.00069	0.004383	0.8744	-0.00928	0.007897
Clinic Connectedness					
Connected to specific physician	0.3181	0.05024	<.0001	0.2197	0.4166
Connected to specific practice	reference	n/a	n/a	n/a	n/a
Lives in Urban Area	0.2569	0.1589	0.1059	-0.05456	0.5684
Lives in Area with Low Physical Food Access	0.09945	0.07799	0.2023	-0.05342	0.2523
Percentage of Area Living in Group Quarters	-0.00019	0.000060	0.0013	-0.00031	-0.00008
Lives in Area with Low Vehicle Access	0.1198	0.05586	0.0320	0.01027	0.2293
ZIP-level Unemployment Rate	0.2601	0.03946	<.0001	0.1825	0.3377
ZIP-level Median Household Income	-0.00001	1.988E-6	<.0001	-0.00002	-8.84E-6
ZIP-level Poverty Rate	-0.03147	0.01401	0.0255	-0.05905	-0.00389
ZIP-level Segregation	0.003079	0.003968	0.4385	-0.00473	0.01089

eTable 10: Full models for association between ZIP-level nutrition resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.1161	1.1836	<.0001	25.7958	30.4364
ZIP-level nutrition resources	-0.07146	0.03122	0.0234	-0.1331	-0.00980
ZIP-level afterschool resources	0.002639	0.02650	0.9208	-0.04967	0.05495
Age, years	-0.04949	0.002011	<.0001	-0.05344	-0.04555
Female	-1.3792	0.04395	<.0001	-1.4654	-1.2931
Race/ethnicity					
Asian/Multi/Other	-2.5116	0.09329	<.0001	-2.6944	-2.3287
Non-Hispanic Black	0.9650	0.09756	<.0001	0.7738	1.1562
Hispanic	0.7272	0.1081	<.0001	0.5152	0.9392
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2787	0.07082	<.0001	-0.4175	-0.1399
High School Diploma	0.09695	0.07549	0.1991	-0.05102	0.2449
Less than High School Diploma	0.3870	0.09117	<.0001	0.2083	0.5657
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1858	1.0208	0.8555	-1.8150	2.1866
Medicare and Medicaid	0.06642	1.0240	0.9483	-1.9406	2.0735
Medicaid	0.6927	1.0215	0.4977	-1.3095	2.6948
Medicaid	-0.5000	1.0230	0.6250	-2.5050	1.5051
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.7143	0.09604	<.0001	0.5261	0.9026
History of Hypertension	2.7290	0.05550	<.0001	2.6202	2.8378
History of Coronary Heart Disease	-0.4139	0.08601	<.0001	-0.5825	-0.2453
History of Diabetes Mellitus	2.4211	0.07471	<.0001	2.2747	2.5676

eTable 10: Full models for association between ZIP-level nutrition resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	0.5484	0.07350	<.0001	0.4044	0.6925
History of Osteoarthritis	1.3187	0.05467	<.0001	1.2115	1.4259
Charlson Comorbidity Score	0.06712	0.01268	<.0001	0.04227	0.09197
Clinic Visits	-0.00069	0.004383	0.8750	-0.00928	0.007900
Clinic Connectedness					
Connected to specific physician	0.3185	0.05024	<.0001	0.2200	0.4170
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.2529	0.1588	0.1113	-0.05838	0.5642
Lives in Area with Low Physical Food Access	0.1009	0.07792	0.1955	-0.05185	0.2536
Percentage of Area Living in Group Quarters	-0.00020	0.000060	0.0009	-0.00032	-0.00008
Lives in Area with Low Vehicle Access	0.1176	0.05585	0.0352	0.008130	0.2271
ZIP-level Unemployment Rate	0.2684	0.03881	<.0001	0.1921	0.3447
ZIP-level Median Household Income	-0.00001	1.972E-6	<.0001	-0.00002	-8.48E-6
ZIP-level Poverty Rate	-0.03270	0.01396	0.0199	-0.06020	-0.00521
ZIP-level Segregation	0.003113	0.003967	0.4332	-0.00470	0.01092

eTable 11: Full models for association between ZIP-level housing resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	115.70	11.1188	<.0001	93.9116	137.50
ZIP-level housing resources	-0.04612	0.05585	0.4106	-0.1567	0.06446
ZIP-level afterschool resources	-0.03286	0.04586	0.4755	-0.1240	0.05828
Age, years	0.1521	0.009429	<.0001	0.1337	0.1706
Female	-0.6839	0.1930	0.0004	-1.0622	-0.3055
Race/ethnicity					
Asian/Multi/Other	-1.2014	0.4952	0.0153	-2.1720	-0.2308
Non-Hispanic Black	2.8013	0.3960	<.0001	2.0251	3.5774
Hispanic	0.5064	0.5619	0.3675	-0.5950	1.6078
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	0.02428	0.3181	0.9392	-0.5992	0.6478
High School Diploma	0.1732	0.3236	0.5924	-0.4610	0.8074
Less than High School Diploma	0.6220	0.3914	0.1121	-0.1452	1.3893
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	8.3527	10.9765	0.4467	-13.1616	29.8671
Medicare and Medicaid	7.8728	10.9784	0.4733	-13.6453	29.3910
Medicaid	8.5660	10.9772	0.4352	-12.9499	30.0818
Medicaid	8.4728	10.9781	0.4402	-13.0447	29.9903
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.01463	0.4091	0.9715	-0.8165	0.7873
History of Coronary Heart Disease	-2.7190	0.2620	<.0001	-3.2325	-2.2055
History of Diabetes Mellitus	0.1079	0.2325	0.6426	-0.3478	0.5635
History of Depression	-0.9568	0.3076	0.0019	-1.5596	-0.3539

eTable 11: Full models for association between ZIP-level housing resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.5000	0.2009	0.0128	-0.8939	-0.1062
Charlson Comorbidity Score	-0.05959	0.04502	0.1856	-0.1478	0.02865
Clinic Visits	-0.02840	0.01601	0.0760	-0.05978	0.002975
Clinic Connectedness					
Connected to specific physician	-1.9594	0.2580	<.0001	-2.4651	-1.4538
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.2234	0.5896	0.7049	-0.9332	1.3799
Lives in Area with Low Physical Food Access	-0.6380	0.3321	0.0548	-1.2892	0.01327
Percentage of Area Living in Group Quarters	-0.00025	0.000262	0.3352	-0.00077	0.000261
Lives in Area with Low Vehicle Access	0.2689	0.2251	0.2324	-0.1725	0.7102
ZIP-level Unemployment Rate	0.1919	0.1055	0.0702	-0.01598	0.3998
ZIP-level Median Household Income	5.33E-7	4.993E-6	0.9151	-9.33E-6	0.000010
ZIP-level Poverty Rate	0.003603	0.03442	0.9168	-0.06460	0.07180
ZIP-level Segregation	-0.00127	0.01007	0.8999	-0.02117	0.01863

eTable 12: Full models for association between ZIP-level nutrition resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	115.52	11.1170	<.0001	93.7336	137.31
ZIP-level nutrition resources	0.01167	0.07270	0.8728	-0.1325	0.1559
ZIP-level afterschool resources	-0.06660	0.05852	0.2582	-0.1829	0.04971
Age, years	0.1522	0.009429	<.0001	0.1337	0.1707
Female	-0.6823	0.1930	0.0004	-1.0606	-0.3039
Race/ethnicity					
Asian/Multi/Other	-1.2077	0.4952	0.0147	-2.1782	-0.2371
Non-Hispanic Black	2.7981	0.3960	<.0001	2.0218	3.5744
Hispanic	0.5101	0.5622	0.3643	-0.5919	1.6120
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
education					
College or >	0.01868	0.3181	0.9532	-0.6048	0.6421
High School Diploma	0.1716	0.3236	0.5958	-0.4626	0.8059
Less than High School Diploma	0.6218	0.3915	0.1122	-0.1455	1.3891
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	8.3894	10.9765	0.4447	-13.1251	29.9038
Medicare and Medicaid	7.9053	10.9784	0.4715	-13.6130	29.4235
Medicaid	8.6004	10.9773	0.4334	-12.9155	30.1163
Medicaid	8.5087	10.9781	0.4383	-13.0089	30.0263
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.01592	0.4094	0.9690	-0.8183	0.7865
History of Coronary Heart Disease	-2.7161	0.2620	<.0001	-3.2295	-2.2026
History of Diabetes Mellitus	0.1087	0.2325	0.6399	-0.3469	0.5644
History of Depression	-0.9576	0.3076	0.0019	-1.5605	-0.3547

eTable 12: Full models for association between ZIP-level nutrition resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.5002	0.2009	0.0128	-0.8940	-0.1063
Charlson Comorbidity Score	-0.05975	0.04502	0.1845	-0.1480	0.02849
Clinic Visits	-0.02845	0.01601	0.0756	-0.05982	0.002932
Clinic Connectedness					
Connected to specific physician	-1.9589	0.2580	<.0001	-2.4645	-1.4532
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.1603	0.5860	0.7845	-0.9893	1.3098
Lives in Area with Low Physical Food Access	-0.5789	0.3269	0.0768	-1.2201	0.06231
Percentage of Area Living in Group Quarters	-0.00025	0.000262	0.3343	-0.00077	0.000261
Lives in Area with Low Vehicle Access	0.2662	0.2251	0.2371	-0.1752	0.7076
ZIP-level Unemployment Rate	0.2065	0.1045	0.0493	0.000612	0.4124
ZIP-level Median Household Income	1.008E-6	4.966E-6	0.8395	-8.8E-6	0.000011
ZIP-level Poverty Rate	0.003660	0.03453	0.9158	-0.06473	0.07205
ZIP-level Segregation	-0.00086	0.01007	0.9325	-0.02075	0.01904

eTable 13: Full models for association between ZIP-level nutrition resources and low density lipoprotein cholesterol

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	103.76	38.1863	0.0066	28.9153	178.61
ZIP-level nutrition resources	0.09859	0.2309	0.6699	-0.3573	0.5545
ZIP-level afterschool resources	-0.00381	0.1854	0.9837	-0.3706	0.3630
Age, years	-0.3600	0.03023	<.0001	-0.4193	-0.3008
Female	11.7432	0.5645	<.0001	10.6367	12.8497
Race/ethnicity	0	.	.	.	.
Asian/Multi/Other	-2.6927	1.4423	0.0619	-5.5197	0.1343
Non-Hispanic Black	0.7350	1.2077	0.5428	-1.6323	3.1022
Hispanic	0.3468	1.7794	0.8455	-3.1409	3.8345
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1046	0.9328	0.9107	-1.9329	1.7237
High School Diploma	-0.2598	0.9497	0.7844	-2.1212	1.6016
Less than High School Diploma	-0.8496	1.1612	0.4644	-3.1256	1.4264
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	37.5148	37.8147	0.3212	-36.6052	111.63
Medicare and Medicaid	36.1970	37.8181	0.3385	-37.9296	110.32
Medicaid	37.4872	37.8163	0.3216	-36.6360	111.61
Medicaid	35.4040	37.8171	0.3492	-38.7206	109.53
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.6482	1.2438	0.6023	-1.7897	3.0861
History of Hypertension	-4.3457	1.1538	0.0002	-6.6072	-2.0842
History of Coronary Heart Disease	-14.8429	0.7275	<.0001	-16.2689	-13.4170
History of Diabetes Mellitus	-16.1429	0.6619	<.0001	-17.4404	-14.8455

eTable 13: Full models for association between ZIP-level nutrition resources and low density lipoprotein cholesterol

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	1.0979	0.9513	0.2485	-0.7668	2.9626
History of Osteoarthritis	1.0828	0.5853	0.0643	-0.06449	2.2302
Charlson Comorbidity Score	-0.9716	0.1366	<.0001	-1.2394	-0.7038
Clinic Visits	-0.1983	0.04901	<.0001	-0.2944	-0.1023
Clinic Connectedness					
Connected to specific physician	-1.4526	0.8446	0.0855	-3.1081	0.2029
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	-0.4909	1.7202	0.7754	-3.8649	2.8831
Lives in Area with Low Physical Food Access	0.2234	1.0117	0.8252	-1.7604	2.2073
Percentage of Area Living in Group Quarters	0.001870	0.000788	0.0177	0.000325	0.003414
Lives in Area with Low Vehicle Access	-1.1732	0.6607	0.0759	-2.4686	0.1222
ZIP-level Unemployment Rate	0.1519	0.3138	0.6287	-0.4659	0.7698
ZIP-level Median Household Income	-0.00001	0.000015	0.3460	-0.00004	0.000015
ZIP-level Poverty Rate	-0.06528	0.1068	0.5418	-0.2760	0.1454
ZIP-level Segregation	-0.00654	0.03045	0.8301	-0.06656	0.05347

eTable 14: Full models for association between ZIP-level substance abuse resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	7.0576	0.3362	<.0001	6.3986	7.7166
ZIP-level substance abuse resources	-0.00251	0.01460	0.8634	-0.03113	0.02611
ZIP-level afterschool resources	0.01106	0.007376	0.1336	-0.00339	0.02552
Age, years	-0.01059	0.001940	<.0001	-0.01440	-0.00679
Female	-0.1380	0.03843	0.0003	-0.2133	-0.06263
Race/ethnicity					
Asian/Multi/Other	-0.08503	0.08123	0.2952	-0.2443	0.07420
Non-Hispanic Black	0.07012	0.06209	0.2588	-0.05160	0.1918
Hispanic	0.06593	0.08944	0.4611	-0.1094	0.2413
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1646	0.06820	0.0158	-0.2983	-0.03090
High School Diploma	-0.01912	0.06665	0.7742	-0.1498	0.1116
Less than High School Diploma	-0.07235	0.07528	0.3366	-0.2200	0.07529
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	0.2134	0.05612	0.0001	0.1034	0.3234
Medicare and Medicaid	0.03459	0.05765	0.5486	-0.07842	0.1476
Medicaid	0.3912	0.06811	<.0001	0.2577	0.5247
Medicaid	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.1599	0.06505	0.0140	-0.2874	-0.03232
History of Hypertension	0.2365	0.05985	<.0001	0.1191	0.3538
History of Coronary Heart Disease	-0.03921	0.04940	0.4274	-0.1361	0.05764

eTable 14: Full models for association between ZIP-level substance abuse resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	-0.03705	0.05766	0.5205	-0.1501	0.07598
History of Osteoarthritis	-0.1499	0.04010	0.0002	-0.2285	-0.07134
Charlson Comorbidity Score	0.01588	0.008146	0.0513	-0.00009	0.03185
Clinic Visits	0.006502	0.002846	0.0224	0.000922	0.01208
Clinic Connectedness					
Connected to specific physician	-0.08553	0.05430	0.1153	-0.1920	0.02092
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.3470	0.1270	0.0063	0.09804	0.5959
Lives in Area with Low Physical Food Access	-0.07748	0.06097	0.2039	-0.1970	0.04205
Percentage of Area Living in Group Quarters	-0.00001	0.000060	0.8418	-0.00013	0.000106
Lives in Area with Low Vehicle Access	0.04455	0.04429	0.3145	-0.04228	0.1314
ZIP-level Unemployment Rate	0.03710	0.01932	0.0549	-0.00078	0.07499
ZIP-level Median Household Income	1.636E-6	Unable to estimate	Unable to estimate	Unable to estimate	Unable to estimate
ZIP-level Poverty Rate	-0.00359	0.005890	0.5418	-0.01514	0.007953
ZIP-level Segregation	-0.00001	0.001802	0.9950	-0.00354	0.003522

eTable 15: Full models for association between ZIP-level mental health resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	7.0641	0.3371	<.0001	6.4033	7.7250
ZIP-level mental health resources	-0.00348	0.01130	0.7582	-0.02564	0.01868
ZIP-level afterschool resources	0.01159	0.006992	0.0974	-0.00212	0.02530
Age, years	-0.01058	0.001940	<.0001	-0.01438	-0.00678
Female	-0.1382	0.03843	0.0003	-0.2135	-0.06283
Race/ethnicity					
Asian/Multi/Other	-0.08415	0.08130	0.3007	-0.2435	0.07522
Non-Hispanic Black	0.07084	0.06217	0.2545	-0.05103	0.1927
Hispanic	0.06543	0.08946	0.4646	-0.1099	0.2408
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1647	0.06820	0.0158	-0.2984	-0.03095
High School Diploma	-0.01936	0.06665	0.7715	-0.1500	0.1113
Less than High School Diploma	-0.07325	0.07536	0.3312	-0.2210	0.07454
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	0.2135	0.05612	0.0001	0.1035	0.3235
Medicare and Medicaid	0.03499	0.05767	0.5440	-0.07805	0.1480
Medicaid	0.3913	0.06810	<.0001	0.2578	0.5248
Medicaid	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.1597	0.06502	0.0141	-0.2871	-0.03218
History of Hypertension	0.2365	0.05985	<.0001	0.1191	0.3538
History of Coronary Heart Disease	-0.03931	0.04940	0.4262	-0.1362	0.05753
History of Depression	-0.03699	0.05766	0.5212	-0.1500	0.07604

eTable 15: Full models for association between ZIP-level mental health resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.1498	0.04009	0.0002	-0.2284	-0.07123
Charlson Comorbidity Score	0.01585	0.008146	0.0518	-0.00012	0.03182
Clinic Visits	0.006518	0.002846	0.0220	0.000939	0.01210
Clinic Connectedness					
Connected to specific physician	-0.08559	0.05429	0.1150	-0.1920	0.02085
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.3477	0.1268	0.0061	0.09914	0.5962
Lives in Area with Low Physical Food Access	-0.07867	0.06091	0.1966	-0.1981	0.04074
Percentage of Area Living in Group Quarters	-0.00001	0.000060	0.8517	-0.00013	0.000107
Lives in Area with Low Vehicle Access	0.04534	0.04440	0.3072	-0.04169	0.1324
ZIP-level Unemployment Rate	0.03660	0.01940	0.0592	-0.00143	0.07462
ZIP-level Median Household Income	1.599E-6	Unable to estimate	Unable to estimate	Unable to estimate	Unable to estimate
ZIP-level Poverty Rate	-0.00359	0.005889	0.5423	-0.01513	0.007956
ZIP-level Segregation	-0.00002	0.001802	0.9931	-0.00355	0.003517

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	118.75	2.4411	<.0001	113.96	123.54
ZIP-level food resources	-0.08047	0.03550	0.0262	-0.1511	-0.00980
ZIP-level afterschool resources	0.06047	0.03336	0.0730	-0.00574	0.1267

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Age, years	0.1657	0.005420	<.0001	0.1550	0.1763
Female	-5.2802	0.1186	<.0001	-5.5126	-5.0477
Race/ethnicity					
Asian/Multi/Other	-2.6721	0.2363	<.0001	-3.1353	-2.2089
Non-Hispanic Black	0.6111	0.2706	0.0239	0.08082	1.1415
Hispanic	-0.7475	0.2728	0.0061	-1.2822	-0.2129
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.02240	0.1940	0.9080	-0.4026	0.3577
High School Diploma	0.4658	0.2125	0.0284	0.04932	0.8823
Less than High School Diploma	0.9903	0.2550	0.0001	0.4905	1.4901
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	-4.3672	2.1456	0.0418	-8.5725	-0.1618
Medicare and Medicaid	-4.2024	2.1674	0.0525	-8.4505	0.04573
Medicaid	-4.6349	2.1479	0.0309	-8.8449	-0.4248
Medicaid	-2.2777	2.1596	0.2916	-6.5105	1.9551
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.9827	0.2700	0.0003	0.4536	1.5119
History of Depression	-0.1126	0.2130	0.5970	-0.5301	0.3048
History of Osteoarthritis	0.5132	0.1754	0.0034	0.1695	0.8570
Charlson Comorbidity Score	0.1840	0.04369	<.0001	0.09834	0.2696
Clinic Visits	-0.05715	0.01445	<.0001	-0.08548	-0.02882
Clinic Connectedness					
Connected to specific physician	-0.6938	0.1282	<.0001	-0.9450	-0.4425

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	-0.4004	0.3700	0.2793	-1.1261	0.3254
Lives in Area with Low Physical Food Access	0.2289	0.1896	0.2274	-0.1429	0.6006
Percentage of Area Living in Group Quarters	-0.00031	0.000146	0.0348	-0.00060	-0.00002
Lives in Area with Low Vehicle Access	-0.00646	0.1455	0.9646	-0.2917	0.2788
ZIP-level Unemployment Rate	0.2795	0.07224	0.0001	0.1373	0.4218
ZIP-level Median Household Income	-0.00002	3.286E-6	<.0001	-0.00002	-9.76E-6
ZIP-level Poverty Rate	-0.02364	0.02254	0.2968	-0.06835	0.02108
ZIP-level Segregation	0.01658	0.006771	0.0154	0.003208	0.02995

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3-4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			7-8
Study design	4	Present key elements of study design early in the paper	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-10
Bias	9	Describe any efforts to address potential sources of bias	10-13
Study size	10	Explain how the study size was arrived at	13
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10-13
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10-13
		(b) Describe any methods used to examine subgroups and interactions	10-13, technical appendix
		(c) Explain how missing data were addressed	10-13
		(d) If applicable, describe analytical methods taking account of sampling strategy	10-13
		(e) Describe any sensitivity analyses	10-13

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	13
		(b) Give reasons for non-participation at each stage	13
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13-14, table 1, etables 2-3
		(b) Indicate number of participants with missing data for each variable of interest	Etables 2-3
Outcome data	15*	Report numbers of outcome events or summary measures	14-15
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-15
		(b) Report category boundaries when continuous variables were categorized	n/a
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14-16, eappendix
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18-19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Association Between Access to Social Service Resources and Cardiometabolic Risk Factors: A Machine Learning and Multi-Level Modeling Analysis

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Manuscript ID	bmjopen-2018-025281.R2
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Complete List of Authors:	Berkowitz, Seth; University of North Carolina at Chapel Hill School of Medicine, General Medicine and Clinical Epidemiology Basu, Sanjay; Stanford University, Departments of Medicine and of Health Research and Policy Venkataramani, Atheendar; University of Pennsylvania, Department of Medical Ethics and Health Policy, Perelman School of Medicine Reznor, Gally; Massachusetts General Hospital, Division of General Internal Medicine Fleegler, Eric; Children's Hospital Boston, Division of Emergency Medicine Atlas, Steven; Massachusetts General Hospital, Division of General Internal Medicine
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SCHOLARONE™
Manuscripts

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3 **Association Between Access to Social Service Resources and Cardiometabolic**
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5 **Risk Factors: A Machine Learning and Multi-Level Modeling Analysis**
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38 Running Title: Social Service Resources and Cardiometabolic Risk

39
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41 Key Words: cardiovascular disease, food insecurity, health disparities,

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43 socioeconomic status
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3 **Objectives:** Interest in linking patients with unmet social needs to area-level
4 resources, such as food pantries and employment centers in one's ZIP code, is
5 growing. However, whether the presence of these resources is associated with
6 better health outcomes is unclear. We sought to determine if area-level resources,
7 defined as organizations that assist individuals with meeting health-related social
8 needs, are associated with lower levels of cardiometabolic risk factors.
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17 **Design:** Cross-sectional.

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20 **Setting:** Data were collected in a primary care network in eastern Massachusetts in
21 2015.
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24 **Participants and Primary and Secondary Outcome Measures:** 123,355

25 participants were included. The primary outcome was body mass index (BMI). The
26 secondary outcomes were systolic blood pressure (SBP), low density lipoprotein
27 cholesterol (LDL), and hemoglobin A1c (HbA1c). All participants were included in
28 BMI analyses. Participants with hypertension were included in SBP analyses.
29 Participants with an indication for cholesterol lowering were included in LDL
30 analyses, and participants with diabetes mellitus were included in HbA1c analyses.
31 We used a random forest-based machine-learning algorithm to identify types of
32 resources associated with study outcomes. We then tested the association of ZIP-
33 level selected resource types (three for BMI, two each for SBP and HbA1c analyses,
34 and one for LDL analyses) with these outcomes, using multi-level models to account
35 for individual-level, clinic-level, and other area-level factors.
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52 **Results:** Resources associated with lower BMI included more food resources (-0.08
53 kg/m² per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m²),
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3 employment resources (-0.05 kg/m², 95%CI -0.11 to -0.002 kg/m²), and nutrition
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5 resources (-0.07 kg/m², 95%CI -0.13 to -0.01 kg/m²). No area resources were
6
7 associated with differences in SBP, LDL, or HbA1c.
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10 **Conclusions:** Access to specific local resources is associated with better BMI. Efforts
11
12 to link patients to area resources, and to improve the resources landscape within
13
14 communities, may help reduce BMI and improve population health.
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Strengths and Limitations of the Study

- Strength: Extensive individual and area-level data
- Strength: Innovative machine learning methods to overcome issues of collinearity and avoid multiple testing
- Strength: Use hierarchical linear modeling to account for data structure
- Limitation: Cross-sectional study
- Limitation: No information on use of resources

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3 Cardiometabolic disease remains the most common cause of morbidity and
4 mortality in the U.S.¹ Though better control of cardiometabolic risk factors could
5 substantially reduce this morbidity and mortality, individuals with low
6 socioeconomic status (SES) are less likely to achieve recommended goals.² Among
7 the reasons for this are patient-reported health-related social needs, including food
8 insecurity, housing instability, and lack of transportation. These health-related
9 social needs have been associated with higher levels of important cardiometabolic
10 risk factors including increased body mass index (BMI), systolic blood pressure
11 (SBP), low density lipoprotein cholesterol (LDL), and hemoglobin A1c (HbA1c), even
12 after adjusting for factors like race/ethnicity, income, and education.³⁻⁸ Proposed
13 mechanisms linking health-related social needs to cardiometabolic risk factors
14 including reduced dietary quality, cost-related medication underuse, reduced
15 cognitive 'bandwidth' to attend to health, and disruptions in clinical care.⁹⁻¹¹

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36 Healthcare systems are increasingly interested in working with community partners
37 to help link their patients to local resources, such as food pantries or housing
38 agencies, to help meet health-related social needs.¹²⁻¹⁶ This approach is exemplified
39 by the Accountable Health Communities initiative from the Centers for Medicare &
40 Medicaid Services, which involves screening for adverse social circumstances and
41 linking those who screen positive to community resources.¹⁷ However, there remain
42 significant gaps in knowledge regarding such approaches. Critically, healthcare
43 systems need to know which organizations to partner with, and potentially what
44 types of resources to invest in.¹⁸ The specific resources that best address a

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3 particular health-related need may not be straightforward. For example, a food
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5 pantry could help alleviate food insecurity, but so could employment.
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10 To help address these issues, and inform further interventions, we sought to study
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12 associations between area resources and cardiometabolic risk factors in a large
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14 primary care network. Our goal was to understand which resource types were
15
16 associated with improved levels of BMI, SBP, LDL, and HbA1c, and to determine
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18 whether area resources had stronger associations with cardiometabolic risk factors
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20 for conditions that are less amenable to clinical management.
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26 **Methods**

27 *Setting and Study Sample*

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29 Data for this study came from two primary sources: an asset mapping of community
30
31 resources, and electronic health records. The asset mapping came from the
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33 HelpSteps database, a comprehensive asset mapping of area resources in eastern
34
35 Massachusetts.¹⁹ The clinical records came from a primary care network in eastern
36
37 Massachusetts, a network of 18 primary care practices, including hospital-based,
38
39 academic, and community health center sites. All adult (age ≥ 18 years) primary
40
41 care patients seen between January 1, 2012 and December 31, 2015 were included.
42
43 Data were current on December 31, 2015. The most recent patient address was
44
45 geocoded for the study. Patients without available addresses were excluded—prior
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47 work has shown that only 0.15% of patients in this cohort could not be geocoded.²⁰
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3 The Partners Healthcare Human Research Committee approved this analysis, which
4 entailed use of secondary data without patient contact (Protocol Number:
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6 2017P000964).
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10 11 12 *Patient and Public Involvement* 13

14 The study research question was developed in reference to patient priorities
15 regarding the incorporation of neighborhood factors that promote health into
16 population health management. Patients were not involved in the design of the
17 study or in recruitment. We plan to disseminate study results via open-access
18 publication.
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29 *Area Resources* 30

31 HelpSteps (www.helpsteps.com) is a web and mobile screening and referral system
32 for social needs. Originally launched in 2010, the system uses a database of social
33 services throughout the greater Boston area to connect families to appropriate
34 services. The database is maintained in collaboration between Boston Children's
35 Hospital and the Mayor's Health Line at the Boston Public Health Commission.
36 Every agency is contacted at least once per year to maintain the accuracy of the data
37 and to grow the database. HelpSteps contains information on area resources across
38 16 non-mutually exclusive domains: health, housing, food employment, violence,
39 safety, substance abuse, mental health, education, parenting, nutrition, after school,
40 sexual health, transportation, diabetes, and care transitions. An example of
41 organizations that would be in the food domain are food pantries. The employment
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3 domain would consist of job placement or job training services. And the nutrition
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5 domain would include organizations that provide food counseling. Agencies
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7 providing multiple resources could be included in more than one domain. Because
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9 individual-level data for this study came from 2015, we used information from
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11 HelpSteps that was current as of 2015. For this study, 'area resources' are defined as
12
13 the number of organizations found in the HelpSteps database providing assistance
14
15 for a given domain and within a given geographic area.
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20 After geocoding the addresses for both individuals and the area resource
21
22 organization, we created counts, for each individual, of how many resources for each
23
24 domain were within the same geographic area as they were. We did this at 4
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26 geographic levels in roughly increasing order of size: census tract (using U.S. Census
27
28 2010 boundaries), ZIP code tabulation area (which we refer to throughout this
29
30 paper as 'ZIP' level, owing to common use of the term, again using U.S. Census 2010
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32 boundaries), 'neighborhood' (e.g. Allston, Roxbury, a designation based on Boston
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34 city planning that may better capture actual movement patterns), and county.
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41 *Clinical Outcomes*

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43 To assess clinical outcomes, we calculated the mean of all values recorded in 2015
44
45 from individual's electronic health record for the following measurements: body
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47 mass index (in kg/m²), systolic blood pressure (in mm Hg), low-density lipoprotein
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49 cholesterol (in mg/dL) and HbA1c (%). All values were obtained in the process of
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51 usual care.
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Covariates

To account for possible confounding of the association between area resources and health outcomes, we collected the following variables from the electronic health record: age (years), gender (male or female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or Asian/other/multi), education (less than high school diploma, high school diploma [including GED], or greater than high school diploma), insurance (commercial, Medicare, Medicaid [including dual-eligibles], and uninsured/self-pay), number of clinic visits in 2015, primary language (English vs. other), connectedness to their primary care clinic using previously validated algorithm²¹, and comorbidity (Charlson comorbidity score, and individual indicators of depression, hypertension, coronary heart disease, osteoarthritis, and diabetes). To account for area-level differences from factors other than resources, we used data from the U.S. Census' American Community Survey (5-year estimates 2010-2015) and the USDA's Food Access Research Atlas: median household income, percent living in poverty, 'food desert' status [low-income, low food access census tract at 1/2 mile in urban areas and 10 miles in rural areas], unemployment rate, proportion of the area population living in group quarters (e.g., those living in a nursing facility unlikely to be exposed to area-level conditions), vehicle access, and housing segregation.^{22,23}

Statistical analysis

In this study, we wanted to evaluate the relationship between many resources types and cardiometabolic risk factors. A secondary goal of our study was to help

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3 understand the relationship that specific geographic levels and resource types had
4 with clinical outcomes. Because the nested structure of our data violate the
5 statistical independence assumption that underlies parametric, regression-based
6 variable selection approaches (such as forward, backward, or step-wise selection),
7 and to avoid multiple hypothesis testing that may lead to the identification of
8 spurious associations, we employed a non-parametric machine learning technique
9 called variable selecting using random forest (VSURF) to screen through variables in
10 the derivation set.^{24,25} This was done using a derivation dataset, which consisted of a
11 random partition of the entire dataset. Finally, we used multi-level modeling in the
12 test set (not used in the derivation stage) to test a small number of candidate
13 variables identified by VSURF as being most important to explaining variations in
14 the derivation set. VSRUF is described in more detail in the technical appendix and
15 eFigure 1.

36 Multi-level modeling

37
38 In the test dataset, we fit multi-level linear mixed models to test the association
39 between variables identified in the VSURF step and the outcome of interest. The BMI
40 model included all study participants. The SBP model included those with a
41 diagnosis of hypertension. The LDL model included those with common diagnoses
42 (hypertension, diabetes, coronary heart disease, cerebrovascular disease, congestive
43 heart failure) where LDL lowering is most beneficial. The HbA1c models included
44 those with a diagnosis of diabetes. The models used fixed effects to adjust for age,
45 gender, race/ethnicity, education, insurance, number of clinic visits, language, clinic
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3 connectedness, comorbidity, and census tract level median household income,
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5 poverty rates, 'food desert' status, unemployment, numbers living in group quarters,
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7 vehicle access, and segregation. To account for clustering within practices, we
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9 included a practice-level random effects term. To account for area-level clustering,
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11 we used a ZIP-level random effects term. These were fit as crossed effects models
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13 (i.e., we did not nest practices within ZIP codes) to allow for the fact that patients
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15 are often seen in practices outside of their ZIP code of residence.
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22 Falsification tests

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24 To reduce the possibility that observed associations due to other unmeasured
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26 characteristics of the area, rather than the specific area resource tested, we also
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28 conducted falsification analyses. To do this, we used the same modeling approach as
29
30 above, but tested for the association between area after school resources for
31
32 children and the outcome of interest. Our reasoning was that, since there was
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34 unlikely to be any direct effect of afterschool resources for children on adult body
35
36 mass index, any observed association would reflect unmeasured area-
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38 characteristics not appropriately adjusted for in our model (such as high levels of
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40 civic engagement or community organization, or other beneficial resources).
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48 Variations in clinical management

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50 To help explore whether variations in the intensity of clinical management could
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52 explain whether community resources were associated with health outcomes, we
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54 also used the above modeling approach to test whether area resources were
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3 associated with SBP in those *without* a diagnosis of hypertension. The primary care
4 network in the study has quality improvement program that emphasize the
5 importance of SBP, LDL, and HbA1c control in appropriate clinical populations.
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7 Since BMI (in any population) and SBP control in those without a diagnosis of
8 hypertension are not included in these programs, we reasoned that area resources
9
10 may be more important when clinicians are not intensively attempting to impact an
11 outcome. We focused on BMI and systolic blood pressure among those *without*
12 hypertension for this because BMI and SBP are routinely measured at all practice
13 visits for all patients.
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26 Because of its mechanistically plausible relationship with BMI, we used the
27 association between ZIP-level food resources and BMI as the primary outcome, with
28 secondary analyses being the associations between other VSURF selected area
29 resources and clinical outcomes.
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38 Robustness checks

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43 In addition to the main analyses, we conducted a series of robustness checks that
44 examined whether different specifications of resources in the area (e.g. resources
45 per capita or resources per capita living in poverty) or different functional forms
46 (e.g. including polynomial terms or using splines) would alter the observed
47 associations between area-level resources and outcomes. We also conducted
48 analyses restricted to those with indicators of lower socioeconomic status (high
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3 school diploma or lower educational attainment, living in a ZIP where > 15% of
4 individuals are in poverty) to ensure the results were applicable to those most likely
5 to utilize the resources studied.
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12 A p-value of < 0.05 was taken to indicate statistical significance. Analyses were
13 conducted in SAS Version 9.4 (Cary, NC), Stata 14 (College Station, TX), and R
14 version 3.3.4 (Vienna, Austria).
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20 21 22 **Results**

23
24 Overall, 123,355 participants were included in the study. All participants were
25 eligible for the BMI analyses. Based on inclusion criteria, 43,509 were included in
26 the hypertension analyses, 46,940 were included in the LDL analyses, and 13,127
27 were included in the diabetes analyses. Demographic characteristics of the overall
28 sample are presented in Table 1. Demographic characteristics of the samples used in
29 the hypertension, LDL cholesterol, and diabetes analyses are presented in eTables 1-
30 3. Overall, the mean age was 52.4 (SD 16.9) years, the sample was 41.5% male,
31 82.1% non-Hispanic white, 5.8% non-Hispanic black, and 6.5% Hispanic. The
32 median number of years participants were followed in our network was 9
33 (intraquartile range (IQR): 3, 10), and the median number change of address per
34 year followed was 0.1 (IQR 0.1, 0.25), suggesting that participants resided at their
35 current address for the majority of their time in our network.
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3 In general, individuals living in areas with more resources were had lower
4 educational attainment and higher rates of Medicaid insurance coverage (eTable 4).
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8 Maps depicting the distribution of the resources are presented in Figure 1 and
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10 eFigures 2-3.
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15 The mean BMI in the sample was 27.8 (SD 6.2) kg/m². In the hypertension analyses,
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17 the mean BP was 131.6 (SD 15.8) mmHg. In the LDL analyses, the mean LDL was
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19 102.9 (SD 39.8) mg/dL, and in the diabetes analyses the mean HbA1c was 7.1 (SD
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21 1.5)%.
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26 Among geographic levels assessed, all resources selected were at the ZIP level
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28 (Table 2). For the BMI analyses, the selected resources were ZIP level food
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30 resources, ZIP level employment resources, and ZIP level nutrition resources. For
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32 hypertension analyses, the selected resources were ZIP housing and ZIP nutrition
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34 resources. For LDL analyses, the only selected resource was ZIP nutrition resources.
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36 For diabetes analyses, the selected resources were ZIP mental health and ZIP
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38 substance use resources.
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45 For the BMI analyses, we tested the association between selected resources and
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47 BMI, adjusting for the factors described in the statistical analysis section, and
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49 accounting for clustering at the clinic and ZIP level with multi-level linear mixed
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51 models. We found that resources associated with lower BMI included more food
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53 resources (-0.08 kg/m² per additional resource, 95% Confidence Interval[CI] -0.13
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3 to -0.03 kg/m², p= .001), employment resources (-0.05 kg/m², 95%CI -0.11 to -0.002
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5 kg/m², p=.04), and nutrition resources (-0.07 kg/m², 95%CI -0.13 to -0.01 kg/m²,
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7 p=.02) (full models for these and all robustness checks in eAppendix tables 5-16).

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10 Table 3 compares mean BMI and obesity prevalence at selected numbers of
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12 resources, adjusted for the other factors in the model. For example, the mean BMI in
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14 neighborhoods with the median (0) number of food resources was 27.8 kg/m²,
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16 while the mean BMI in neighborhoods in the 75th percentile (3 resources) was 27.5
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18 kg/m², and the 90th percentile (8 resources) was 27.1 kg/m². Falsification tests
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20 found the expected lack of association between afterschool resources and BMI
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22 (p=.67).
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29 Robustness checks found that our results did not vary substantially with other
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31 specifications of area-level resources (eTables 5-7).
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36 In the hypertension analyses, neither housing resources (-0.05 mm Hg per
37
38 additional resource, 95%CI -0.16 to 0.06 mm Hg, p=.41) nor nutrition resources
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40 (0.01 mm Hg, 95%CI -0.13 to 0.16 mm Hg, p=.87) were associated with systolic
41
42 blood pressure after adjustment for individual level and area level characteristics. In
43
44 LDL analyses, nutrition resources (0.10 mg/dL per additional resource, 95%CI -0.36
45
46 to 0.55 mg/dL, p=.67) were not associated with LDL cholesterol in adjusted models.
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49 In diabetes analyses, neither substance abuse resources (-0.003% per additional
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51 resource, 95%CI -0.03 to 0.02%, p=.86) nor mental health resources were
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53 associated with HbA1c (-0.003 %, 95%CI -0.03 to 0.02%, p=.76).
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6 In analyses looking at systolic blood pressure among those without a diagnosis of
7 hypertension (i.e., those with no reason for clinical management of blood pressure),
8 food resources were associated with lower systolic blood pressure in linear mixed
9 models adjusted for the same factors as above (-0.08 mm Hg per additional
10 resource, 95%CI -0.15 to -0.01 mm Hg, $p=.03$). Mean systolic blood pressure was
11 approximately 1 mm Hg lower at the 95th percentile (118.9 mm Hg) of food
12 resources compared with the 50th percentile (119.8 mm Hg).
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24 Full models for all analyses are presented in eTables 8-16.
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29 Discussion

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31 This study assessed the relationship among area resources and cardiometabolic risk
32 factors. We found that increasing numbers of food, employment, and nutrition
33 resources was associated with lower BMI, and lower systolic blood pressure among
34 those without hypertension. The magnitude of the difference was meaningful at the
35 population level, as the 0.7 kg/m² difference in BMI between individuals in a well-
36 resourced versus poorly resourced ZIP is similar to the 0.6 increase kg/m² in BMI in
37 the overall U.S. population from 2006 to 2016.²⁶
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50 Conversely, we found that area resources were not associated with systolic blood
51 pressure among those with hypertension, LDL cholesterol among those with an
52 indication for LDL lowering, or hemoglobin A1c among those with diabetes. This
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3 suggests that the relationship between area resources and cardiometabolic risk
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5 factors may vary based on whether these factors are targets of intensive clinical
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7 management.
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12 This study enhances our knowledge regarding the association of area-level factors
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14 and cardiometabolic risk factors. Prior studies have consistently found that adverse
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16 area-level factors, such as poverty, are associated with increased cardiometabolic
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18 risk, even when adjusting for individual-level factors, such as income.^{2,27-29}
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22 However, we did not know whether the presence of area resources that might
23
24 plausibly support health, such as food and nutrition resources, would be associated
25
26 with lower cardiometabolic risk.
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31 The positive and negative associations between community resources and
32
33 cardiometabolic risk factors may have important public health implications. The
34
35 association between increased area resources and lower BMI suggests that efforts to
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37 help link patients to community resources, and to help improve the resources
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39 landscape within communities, may be a successful strategy for improving
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41 population health, particularly for risk factors such as BMI where clinical
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43 management may not be prioritized.^{13,14,30} This is reinforced by the finding that SBP,
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45 among those without hypertension, is lower in those living in areas with more
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47 resources. Since SBP does not come under clinical management for those without
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49 hypertension, this finding supports the potential for area resources to impact
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51 population health, and is consistent with guidelines that recommend lifestyle, rather
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3 than pharmacologic, approaches to pre-hypertension treatment.³¹ Future work in
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5 this area should investigate whether interventions that link individuals to area
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7 resources show clinical benefits.
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12 Our finding should be interpreted in light of several limitations. We did not have
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14 access to data regarding use of the resources. This means that we do not know
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16 whether individuals made use of the resources in their community. In light of this,
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18 the association between ZIP-level resources and outcomes could be viewed
19
20 analogously to an 'encouragement design' intervention. This means that the
21
22 association estimated in this study is likely different than the association that would
23
24 be estimated if analyzing those who were known to use the resource. That
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26 association is clearly of policy interest, and should be examined in future work.
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30 While we adjusted for several individual-level and area-level socioeconomic status
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32 indicators in order to capture the multidimensional nature of socioeconomic status
33
34 and, thus, reduce confounding, it is possible that residual confounding, owing to
35
36 unmeasured characteristics, exists, which would tend to reduce the observed
37
38 associations between area-resources and outcomes. Additional unmeasured
39
40 covariates that could affect the observed associations include local culture, and the
41
42 quality of the resources available. Devising methodology to determine the quality of
43
44 the services provided to help meet health-related social needs is pressing, and will
45
46 be an important direction for future investigation. Next, our study was cross-
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48 sectional, and thus we cannot establish time-ordering between the exposure and the
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50 cardiometabolic outcomes. However, we think it is less likely that lower BMI would
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3 drive individuals into areas with more resources than vice versa, as areas with
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5 higher resources tended to have other adverse features, such as lower income and
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7 higher poverty, which are likely more salient considerations for those choosing
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9 where to live. Finally, because of the relatively high residential stability within this
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11 primary care population, we only examined the association between current area of
12
13 residence and the study outcomes. However, for those who do move, this could lead
14
15 to misclassification, which would tend to bias results to the null. These limitations
16
17 are balanced by several strengths. We had access to a detailed mapping of area
18
19 resources, along with detailed individual-level health information. Further, in
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21 addition to the multi-level framework we used, the use of falsification tests
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23 demonstrated that unadjusted area-level factors are not likely to explain the
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25 observed results.
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34 In summary, ZIP-level food, employment, and nutrition resources were associated
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36 with BMI differences that were clinically meaningfully and statistically significant.
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38 Further, the association between area resources and cardiometabolic risk factors
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40 differed based on the specific risk factor. Investing in area resources and linkage
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42 programs may be an important way to help reduce cardiometabolic risk for
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44 vulnerable individuals, especially for situations not under intensive clinical
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46 management.
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Guarantor: Seth A. Berkowitz had full access to all of the data in the study and takes full responsibility for the work as a whole, including the study design, access to data, the integrity of the data, the accuracy of the data analysis, and the decision to submit and publish the manuscript.

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Table 1: Demographics of study sample

	N=123,355
	Mean (SD) or n (%)
Age	52.42 (16.89)
Male	51665 (41.9)
Race/ethnicity	
Asian/Multi/Other	6880 (5.6)
Non-Hispanic Black	7203 (5.8)
Hispanic	8039 (6.5)
Non-Hispanic White	101233 (82.1)
Education	
College or >	56302 (45.6)
High School Diploma	36572 (29.6)
Less than High School Diploma	18051 (14.6)
Unknown/Declined	12430 (10.1)
Insurance	
Private	75787 (61.4)
Medicare and Medicaid	8602 (7.0)
Medicaid	20934 (17.0)
Medicare	17911 (14.5)
Self-pay	121 (0.1)
English is Primary Language	112720 (91.4)
History of Hypertension	43509 (35.3)
History of Coronary Heart Disease	9275 (7.5)
History of Diabetes Mellitus	13127 (10.6)
History of Depression	10300 (8.3)
History of Osteoarthritis	23707 (19.2)
Charlson Comorbidity Score	1.72 (2.23)
Clinic Visits	6.57 (5.77)
Clinic Connectedness	
Connected to specific physician	80345 (65.1)
Connected to specific practice	34018 (27.6)
Other	8992 (7.3)
Lives in Urban Area	91095 (96.4)
ZIP-level Unemployment Rate, %	4.71 (1.60)
ZIP-level Median Household Income, \$	82309.16 (31758.79)
ZIP-level Poverty Rate, %	8.70 (6.72)
ZIP-level Segregation*	69.51 (21.05)
Body Mass Index, kg/m ²	27.84 (6.24)
Systolic Blood Pressure, mm Hg	124.36 (14.96)

LDL cholesterol, mg/dL	110.83 (39.95)
Hemoglobin A1c, %	5.94 (1.22)

*Segregation index is a dissimilarity measure of the extent to which groups other than non-Hispanic whites are distributed like non-Hispanic whites. 0 represents complete integration and 100 represents complete segregation.

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Table 2: Distribution of the Number of Resources in the Selected Resource Categories

BMI Analyses							
Resource*	Minimum	25 th Percentile	50 th Percentile	75 th Percentile	90 th Percentile	95 th Percentile	Maximum
Food	0	0	0	3	8	11	27
Employment	0	0	0	4	13	18	33
Nutrition	0	0	0	3	6	12	21
Hypertension Analyses							
Housing	0	0	0	2	8	8	23
Nutrition	0	0	0	3	6	12	21
LDL Analyses							
Nutrition	0	0	0	3	6	12	21
Diabetes Analyses							
Mental health	0	0	0	2	5	6	21
Substance use resources	0	0	1	2	5	6	23

*All resources assessed at ZIP level; table represents counts of each resource type

Table 3: Estimated BMI, in kg/m², by resource level

ZIP-level Food Resources	
50 th Percentile	27.78
75 th Percentile	27.53
90 th Percentile	27.11
95 th Percentile	26.85
ZIP-level Employment Resources	
50 th Percentile	27.78
75 th Percentile	27.56
90 th Percentile	27.07
95 th Percentile	26.80
ZIP-level Nutrition Resources	
50 th Percentile	27.75
75 th Percentile	27.54
90 th Percentile	27.32
95 th Percentile	26.89

Estimates created using least-squares means from fitted multi-level models. The models used fixed effects to adjust for age, gender, race/ethnicity, education, insurance, number of clinic visits, language, clinic connectedness, comorbidity, and census tract level median household income, poverty rates, 'food desert' status, unemployment, numbers living in group quarters, vehicle access, and segregation. To account for clustering within practices, we included a practice-level random effects term. To account for area-level clustering, we used a ZIP-level random effects term. These were fit as crossed effects models (i.e., we did not nest practices within ZIP codes) to allow for the fact that patients are often seen in practices outside of their ZIP code of residence.

Figure 1: Food Resource Density by ZIP

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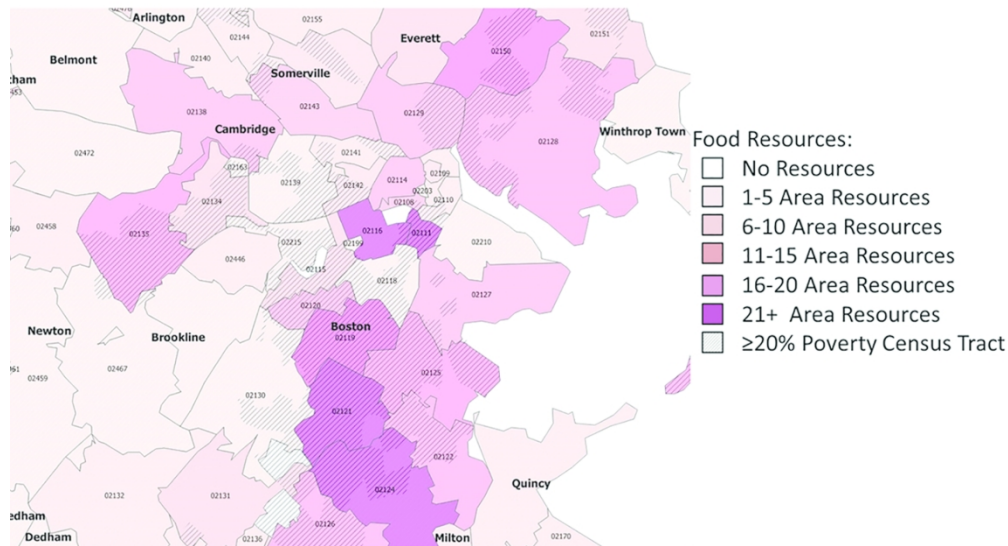


Figure 1

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3 eAppendix for Association Between Area Resources and Cardiometabolic Risk: A Machine
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5 Learning and Multi-Level Modeling Analysis
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Technical Appendix

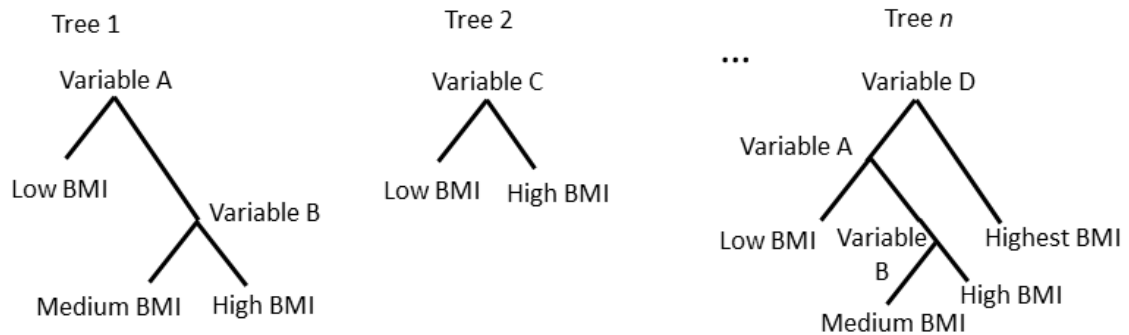
VSURF

The foundation of the VSURF technique is the decision tree (eFigure 1).²¹ To construct a single decision tree, the procedure selects a random subset of variables from the total number of available variables, and selects a variable that best explains the variation in outcome of a bootstrap resample drawn from the derivation sample. For the next split, the variable that best explains the variation within each ‘branch’ of the tree created in the first split is selected. This process is continued until optimal separation is achieved. A ‘forest’ is grown by repeating this process 2000 times, each time randomly drawing a subset of variables and bootstrap resample of the derivation cohort. In the VSURF procedure, 50 forests of 2000 trees were grown in the initial ‘thresholding’ step, which focuses on removing irrelevant variables. Then, 25 forests of 2000 trees, using the remaining variables, were grown to select all variables associated with the response. Finally, 25 forests of 2000 trees were grown, selecting among the remaining variables to eliminate redundancy. After all three steps were completed, we selected up to the top three area resources, as indicated by variable importance factors in the final step, for hypothesis testing in the independent, ‘testing’ sample.

A major advantage of VSURF is that it directly addresses the correlation among variables, as the single best variable is selected at each split and thus the explanatory power is not divided amongst two or more related variables, as in linear regression. Secondly, VSURF allows one to screen through a number of candidate variables while preserving type I error rate, as statistical

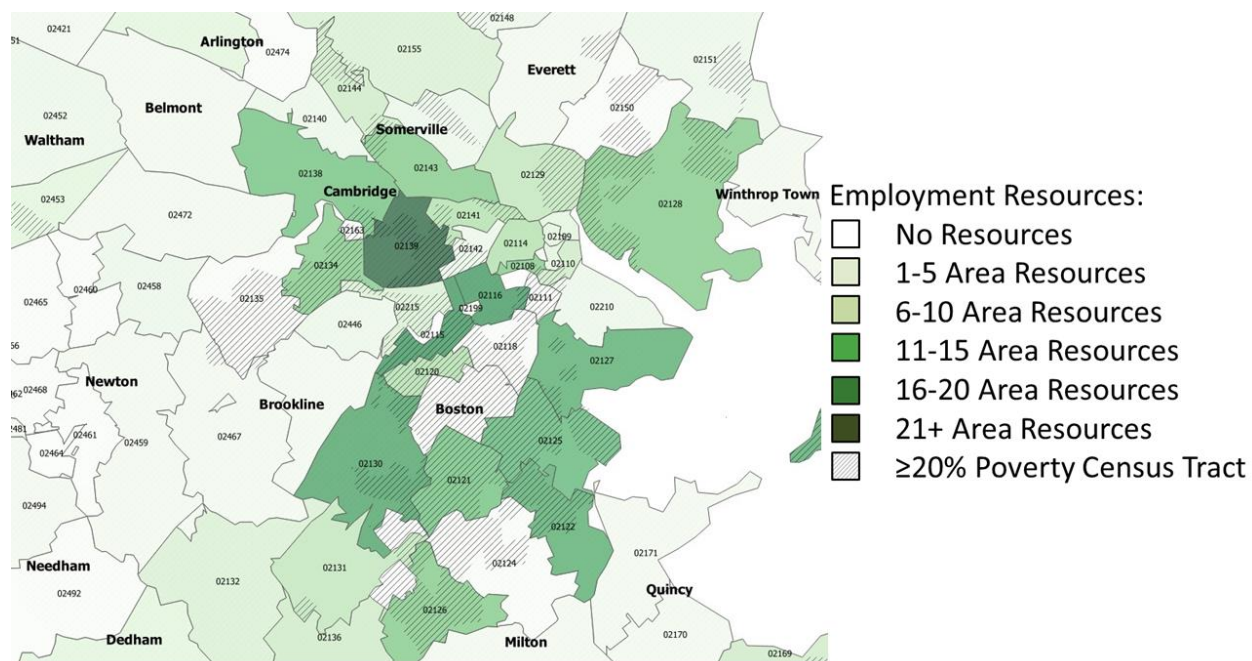
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3 significance testing is not used in the selection of variables, unlike p-value-based selection
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5 algorithms.
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eFigure 1: Depiction of the Variable Selection Using Random Forest (VSURF) Method



From a random subset of variables and a bootstrap resample of individuals in the derivation cohort, a decision tree that optimally splits the sample is created. This process is repeated in a second bootstrap resample with a second randomly selected subset of variables, and so on until n trees ($n=2000$ in this study) are aggregated to create one forest. The forest-growing procedure is repeated 50 times. Then, using variable importance factors, which indicate the variables that are most useful in minimizing the error of predicted values in the 'out-of-bag' sample (those observations that, due to chance, were not selected in the bootstrap resample). After removing the least important variables, the entire process is repeated again, this time growing 25 forests of 2000 trees, in the 'interpretation' step, which focuses on selecting all variables associated with the response. Finally, to deal with correlations between variables, the process is repeated again, growing 25 more forests of 2000 trees, in the 'prediction' step, which focuses on removing redundancy in the final set of variables.

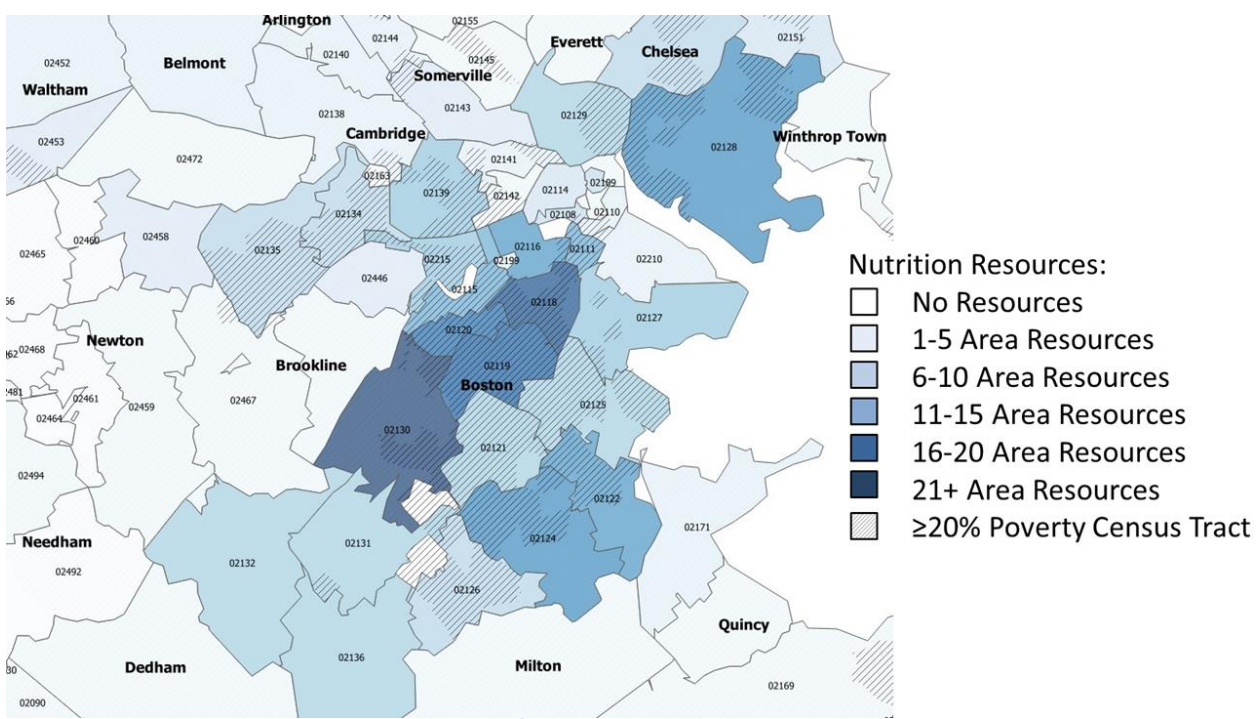
eFigure 2: Employment Resources by ZIP



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eFigure 3: Nutrition Resources by ZIP



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eTable 1: Demographics for Hypertension Study Sample

	N=43,509
	Mean (SD) or n (%)
Age	64.67 (14.05)
Male	21299 (49.0)
Race/ethnicity	
Asian/Multi/Other	1755 (4.0)
Non-Hispanic Black	3138 (7.2)
Hispanic	1983 (4.6)
Non-Hispanic White	36633 (84.2)
Education	
College or >	15660 (36.0)
High School Diploma	15900 (36.5)
Less than High School Diploma	7422 (17.1)
Unknown/Declined	4527 (10.4)
Insurance	
Private	17256 (39.7)
Medicare and Medicaid	6200 (14.2)
Medicaid	6292 (14.5)
Medicare	13756 (31.6)
Self-pay	5 (0.0)
English is Primary Language	39492 (90.8)
History of Coronary Heart Disease	8373 (19.2)
History of Diabetes Mellitus	11085 (25.5)
History of Depression	4745 (10.9)
History of Osteoarthritis	14931 (34.3)
Charlson Comorbidity Score	3.22 (2.57)
Clinic Visits	9.58 (6.77)
Clinic Connectedness	
Connected to specific physician	36233 (83.3)
Connected to specific practice	6978 (16.0)
Other	298 (0.7)
Lives in Urban Area	32075 (96.4)
ZIP-level Unemployment Rate, %	4.85 (1.63)
ZIP-level Median Household Income, \$	80247.61 (31190.75)
ZIP-level Poverty Rate, %	8.67 (6.63)
ZIP-level Segregation	69.19 (21.92)
Body Mass Index, kg/m ²	29.68 (6.40)
History of Obesity	19314 (45.2)
Systolic Blood Pressure, mm Hg	131.60 (15.75)

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LDL cholesterol, mg/dL	102.73 (39.82)
Hemoglobin A1c, %	6.25 (1.34)

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eTable 2: Demographics for LDL Study Sample

	N=46940
	Mean (SD) or n (%)
Age	63.96 (14.33)
Male	22916 (48.8)
Race/ethnicity	
Asian/Multi/Other	1971 (4.2)
Non-Hispanic Black	3401 (7.2)
Hispanic	2285 (4.9)
Non-Hispanic White	39283 (83.7)
Education	
College or >	16940 (36.1)
High School Diploma	17032 (36.3)
Less than High School Diploma	8075 (17.2)
Unknown/Declined	4893 (10.4)
Insurance	
Private	18909 (40.3)
Medicare and Medicaid	6561 (14.0)
Medicaid	7169 (15.3)
Medicare	14296 (30.5)
Self-pay	5 (0.0)
English is Primary Language	42468 (90.5)
History of Hypertension	43509 (92.7)
History of Coronary Heart Disease	9275 (19.8)
History of Diabetes Mellitus	13127 (28.0)
History of Depression	5160 (11.0)
History of Osteoarthritis	15695 (33.4)
Charlson Comorbidity Score	3.14 (2.54)
Clinic Visits	9.46 (6.71)
Clinic Connectedness	
Connected to specific physician	38851 (82.8)
Connected to specific practice	7746 (16.5)
Other	343 (0.7)
Lives in Urban Area	34532 (96.4)
ZIP-level Unemployment Rate, %	4.86 (1.63)
ZIP-level Median Household Income, \$	80079.26 (31173.63)
ZIP-level Poverty Rate, %	8.72 (6.64)
ZIP-level Segregation	68.98 (21.98)
Body Mass Index, kg/m ²	29.63 (6.42)
History of Obesity	20611 (44.7)
Systolic Blood Pressure, mm Hg	130.88 (15.75)

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LDL cholesterol, mg/dL	102.85 (39.81)
Hemoglobin A1c, %	6.28 (1.36)

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eTable 3: Demographics for Diabetes Study Sample

	N=13127
	Mean (SD) or n (%)
Age	64.12 (14.10)
Male	6722 (51.2)
Race/ethnicity	
Asian/Multi/Other	729 (5.6)
Non-Hispanic Black	1415 (10.8)
Hispanic	986 (7.5)
Non-Hispanic White	9995 (76.1)
Education	
College or >	3691 (28.1)
High School Diploma	5115 (39.0)
Less than High School Diploma	3085 (23.5)
Unknown/Declined	1236 (9.4)
Insurance	
Private	4247 (32.4)
Medicare and Medicaid	2609 (19.9)
Medicaid	2654 (20.2)
Medicare	3617 (27.6)
Self-pay	0 (0.0)
English is Primary Language	11138 (84.8)
History of Hypertension	11085 (84.4)
History of Coronary Heart Disease	3316 (25.3)
History of Diabetes Mellitus	13127 (100.0)
History of Depression	1685 (12.8)
History of Osteoarthritis	4605 (35.1)
Charlson Comorbidity Score	4.34 (2.94)
Clinic Visits	11.59 (7.52)
Clinic Connectedness	
Connected to specific physician	10778 (82.1)
Connected to specific practice	2234 (17.0)
Other	115 (0.9)
Lives in Urban Area	9467 (97.4)
ZIP-level Unemployment Rate, %	5.24 (1.67)
ZIP-level Median Household Income, \$	72660.30 (28239.05)
ZIP-level Poverty Rate, %	10.19 (6.83)
ZIP-level Segregation	63.62 (23.80)
Body Mass Index, kg/m ²	31.48 (6.85)
History of Obesity	7427 (57.7)
Systolic Blood Pressure, mm Hg	130.17 (16.09)

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LDL cholesterol, mg/dL	89.25 (37.45)
Hemoglobin A1c, %	7.08 (1.52)

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eTable 4: Demographics of study sample by number of food resources in ZIP code tabulation area

	0 food resources	1 to 7 food resources	≥8 food resources	p
	N=65011	N=42794	N=13028	
	Mean (SD) or n (%)	Mean (SD) or n (%)	Mean (SD) or n (%)	
Age	53.93 (16.13)	51.05 (17.69)	47.95 (16.92)	<0.001
Male	28050 (43.1)	17330 (40.5)	5163 (39.6)	<0.001
Race/ethnicity				<0.001
Asian/Multi/Other	3559 (5.5)	2501 (5.8)	709 (5.4)	
Non-Hispanic Black	2553 (3.9)	2710 (6.3)	1605 (12.3)	
Hispanic	2306 (3.5)	2859 (6.7)	2707 (20.8)	
Non-Hispanic White	56593 (87.1)	34724 (81.1)	8007 (61.5)	
Education				<0.001
College or >	31782 (48.9)	18895 (44.2)	4837 (37.1)	
High School Diploma	18400 (28.3)	13355 (31.2)	3767 (28.9)	
Less than High School Diploma	7373 (11.3)	6762 (15.8)	3449 (26.5)	
Unknown/Declined	7456 (11.5)	3782 (8.8)	975 (7.5)	
Insurance				<0.001
Private	44051 (67.8)	24062 (56.2)	6600 (50.7)	
Medicare and Medicaid	3485 (5.4)	3551 (8.3)	1188 (9.1)	
Medicaid	7319 (11.3)	9011 (21.1)	4075 (31.3)	
Medicare	10128 (15.6)	6093 (14.2)	1149 (8.8)	
Self-pay	28 (0.0)	77 (0.2)	16 (0.1)	
English is Primary Language	61559 (94.7)	38982 (91.1)	9923 (76.2)	<0.001
History of Hypertension	22195 (34.1)	15367 (35.9)	4342 (33.3)	<0.001
History of Coronary Heart Disease	4663 (7.2)	3385 (7.9)	817 (6.3)	<0.001
History of Cerebrovascular Disease	1628 (2.5)	1148 (2.7)	316 (2.4)	0.114
History of Congestive Heart Failure	1941 (3.0)	1793 (4.2)	460 (3.5)	<0.001
History of Diabetes Mellitus	5735 (8.8)	4757 (11.1)	1735 (13.3)	<0.001
History of Depression	4598 (7.1)	4024 (9.4)	1377 (10.6)	<0.001
History of Osteoarthritis	12179 (18.7)	8386 (19.6)	2331 (17.9)	<0.001
Charlson Comorbidity Score	1.70 (2.17)	1.72 (2.28)	1.56 (2.15)	<0.001
Clinic Visits	5.93 (5.18)	7.14 (6.21)	7.19 (6.11)	<0.001
Clinic Connectedness				<0.001
Connected to specific physician	41292 (63.5)	28457 (66.5)	8593 (66.0)	
Connected to specific practice	14727 (22.7)	14337 (33.5)	4435 (34.0)	
Other	8992 (13.8)	0 (0.0)	0 (0.0)	
Lives in Urban Area	52165 (94.3)	29291 (99.4)	7118 (99.9)	<0.001
ZIP-level Unemployment Rate, %	4.27 (1.41)	4.89 (1.51)	5.82 (1.83)	<0.001
ZIP-level Median Household Income, \$	96937.11 (34242.61)	71648.83 (21514.21)	58606.22 (17651.59)	<0.001

ZIP-level Poverty Rate, %	4.91 (4.58)	11.12 (6.26)	15.94 (5.58)	<0.001
ZIP-level Segregation	80.59 (15.85)	65.17 (15.29)	39.16 (20.13)	<0.001
Body Mass Index, kg/m ²	27.64 (6.03)	27.82 (6.34)	28.30 (6.63)	<0.001
History of Obesity	18693 (30.1)	12765 (30.8)	4148 (33.2)	<0.001
Systolic Blood Pressure, mm Hg	124.47 (14.92)	124.27 (15.03)	123.44 (14.80)	<0.001
LDL cholesterol, mg/dL	112.17 (42.48)	109.92 (37.14)	108.83 (35.34)	<0.001
Hemoglobin A1c, %	5.86 (1.12)	5.98 (1.25)	6.13 (1.43)	<0.001

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3 Robustness checks (eTable 5-7)
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7 Results from analyses, adjusted for the same factors as in main model presented in the manuscript,
8 comparing the association of food resources and BMI with different specifications of ZIP-level food
9 resources (count, count per capita, and count per capita living in poverty) show that the association
10 between more area food resources and lower BMI is robust to different specifications of number of
11 resources
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14 eTable 5: Analyses comparing the association of food resources and BMI with different specifications
15 of area-resources

16 Estimated difference in BMI associated 17 with 1 additional ZIP-level resource (95% 18 CI), kg/m ² 19 (main model from manuscript)	20 Estimated difference in 21 BMI associated with 1 22 additional ZIP-level 23 resource per 10000 people 24 (95% CI), kg/m ²	25 Estimated difference in BMI 26 associated with 1 additional 27 ZIP-level resource per 10000 28 people living in poverty 29 (95% CI), kg/m ²
30 -0.08 (-0.13 to -0.03)	31 -0.19 (-0.29 to -0.085)	32 -0.02 (-0.03 to -0.01)

33 Analyses, adjusted for the same factors as in main model presented in the manuscript, including a
34 quadratic and/or cubic term, or restricted cubic splines, to represent the number of ZIP-level resources
35 resulted in worse model fit by Akaike information criterion and Bayes information criterion, suggesting
36 that a linear approximation of the relationship between ZIP-level resources and the modeled outcome is
37 reasonable.
38

39 eTable 6: Model fit statistics from different specifications of ZIP-level food resources

40	41 Akaike information criterion 42 (smaller represents better fit)	43 Bayes information criterion 44 (smaller represents better fit)
45 Linear term only	46 468646.6	47 468640.6
48 Linear plus quadratic	49 468656.5	50 468650.5
51 Linear, quadratic, and cubic	52 468667.8	53 468661.8
54 Restricted cubic spline	55 468656.0	56 468650.0

57 Analyses, adjusted for the same factors as in main model presented in the manuscript, restricted to
58 those with indicators of lower socioeconomic status show that the estimates for the association
59 between additional ZIP-level food resources and BMI are slightly larger than in the overall population,
60 which is consistent with the idea that these resources are beneficial for those with lower socioeconomic
61 status

62 eTable 7: Analyses of association between ZIP-level food resources and body mass index, restricted to
63 those with indicators of lower socioeconomic status
64

Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), kg/m ² (main model from manuscript)	Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), restricted to those with high school diploma or lower educational attainment, kg/m ²	Estimated difference in BMI associated with 1 additional ZIP-level resource (95% CI), restricted to those living in ZIP with > 15% living in poverty, kg/m ²
-0.08 (-0.13 to -0.03)	-0.09 (-0.15 to -0.04)	-0.11 (-0.17 to -0.06)

For peer review only

eTable 8: Full models for association between ZIP-level food resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.2196	1.1796	<.0001	25.9071	30.5320
ZIP-level food resources	-0.08429	0.02512	0.0010	-0.1340	-0.03460
ZIP-level afterschool resources	0.009484	0.02203	0.6674	-0.03404	0.05301
Age, years	-0.04950	0.002011	<.0001	-0.05344	-0.04556
Female	-1.3794	0.04395	<.0001	-1.4656	-1.2933
Race/ethnicity					
Asian/Multi/Other	-2.5117	0.09328	<.0001	-2.6945	-2.3288
Non-Hispanic Black	0.9600	0.09753	<.0001	0.7688	1.1511
Hispanic	0.7277	0.1081	<.0001	0.5157	0.9396
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2793	0.07082	<.0001	-0.4181	-0.1404
High School Diploma	0.09622	0.07549	0.2025	-0.05175	0.2442
Less than High School Diploma	0.3871	0.09117	<.0001	0.2084	0.5658
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1890	1.0208	0.8531	-1.8118	2.1898
Medicare and Medicaid	0.06964	1.0240	0.9458	-1.9374	2.0767
Medicaid	0.6961	1.0215	0.4956	-1.3061	2.6983
Medicaid	-0.4968	1.0230	0.6272	-2.5019	1.5083
Self-pay	reference	n/a	n/a	n/a	n/a
English is Primary Language	0.7128	0.09604	<.0001	0.5246	0.9011
History of Hypertension	2.7291	0.05550	<.0001	2.6203	2.8379
History of Coronary Heart Disease	-0.4141	0.08601	<.0001	-0.5827	-0.2455
History of Diabetes Mellitus	2.4217	0.07471	<.0001	2.2752	2.5681

eTable 8: Full models for association between ZIP-level food resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	0.5488	0.07350	<.0001	0.4048	0.6929
History of Osteoarthritis	1.3188	0.05467	<.0001	1.2116	1.4260
Charlson Comorbidity Score	0.06713	0.01268	<.0001	0.04227	0.09198
Clinic Visits	-0.00068	0.004383	0.8770	-0.00927	0.007911
Clinic Connectedness					
Connected to specific physician	0.3184	0.05024	<.0001	0.2200	0.4169
Connected to specific practice	reference	n/a	n/a	n/a	n/a
Lives in Urban Area	0.2640	0.1580	0.0949	-0.04583	0.5739
Lives in Area with Low Physical Food Access	0.09426	0.07794	0.2265	-0.05851	0.2470
Percentage of Area Living in Group Quarters	-0.00020	0.000060	0.0009	-0.00032	-0.00008
Lives in Area with Low Vehicle Access	0.1189	0.05577	0.0331	0.009564	0.2282
ZIP-level Unemployment Rate	0.2608	0.03829	<.0001	0.1855	0.3361
ZIP-level Median Household Income	-0.00001	1.936E-6	<.0001	-0.00002	-8.81E-6
ZIP-level Poverty Rate	-0.03254	0.01370	0.0183	-0.05952	-0.00555
ZIP-level Segregation	0.002536	0.003897	0.5158	-0.00514	0.01021

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.1779	1.1847	<.0001	25.8554	30.5004
ZIP-level employment resources	-0.05415	0.02624	0.0407	-0.1060	-0.00231

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
ZIP-level afterschool resources	0.01083	0.03215	0.7366	-0.05269	0.07436
Age, years	-0.04951	0.002011	<.0001	-0.05345	-0.04557
Female	-1.3795	0.04395	<.0001	-1.4656	-1.2933
Race/ethnicity					
Asian/Multi/Other	-2.5089	0.09330	<.0001	-2.6918	-2.3260
Non-Hispanic Black	0.9669	0.09755	<.0001	0.7757	1.1581
Hispanic	0.7300	0.1081	<.0001	0.5181	0.9420
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2787	0.07083	<.0001	-0.4175	-0.1399
High School Diploma	0.09646	0.07549	0.2013	-0.05150	0.2444
Less than High School Diploma	0.3880	0.09117	<.0001	0.2093	0.5667
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1930	1.0208	0.8500	-1.8078	2.1938
Medicare and Medicaid	0.07527	1.0240	0.9414	-1.9318	2.0823
Medicaid	0.7010	1.0215	0.4926	-1.3012	2.7032
Medicaid	-0.4922	1.0230	0.6304	-2.4973	1.5128
Self-pay	reference	n/a	n/a	n/a	n/a
English is Primary Language	0.7126	0.09604	<.0001	0.5243	0.9008
History of Hypertension	2.7296	0.05550	<.0001	2.6208	2.8383
History of Coronary Heart Disease	-0.4138	0.08601	<.0001	-0.5824	-0.2452
History of Diabetes Mellitus	2.4215	0.07471	<.0001	2.2751	2.5680
History of Depression	0.5493	0.07350	<.0001	0.4052	0.6933
History of Osteoarthritis	1.3190	0.05467	<.0001	1.2118	1.4261

eTable 9: Full models for association between ZIP-level employment resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Charlson Comorbidity Score	0.06713	0.01268	<.0001	0.04227	0.09198
Clinic Visits	-0.00069	0.004383	0.8744	-0.00928	0.007897
Clinic Connectedness					
Connected to specific physician	0.3181	0.05024	<.0001	0.2197	0.4166
Connected to specific practice	reference	n/a	n/a	n/a	n/a
Lives in Urban Area	0.2569	0.1589	0.1059	-0.05456	0.5684
Lives in Area with Low Physical Food Access	0.09945	0.07799	0.2023	-0.05342	0.2523
Percentage of Area Living in Group Quarters	-0.00019	0.000060	0.0013	-0.00031	-0.00008
Lives in Area with Low Vehicle Access	0.1198	0.05586	0.0320	0.01027	0.2293
ZIP-level Unemployment Rate	0.2601	0.03946	<.0001	0.1825	0.3377
ZIP-level Median Household Income	-0.00001	1.988E-6	<.0001	-0.00002	-8.84E-6
ZIP-level Poverty Rate	-0.03147	0.01401	0.0255	-0.05905	-0.00389
ZIP-level Segregation	0.003079	0.003968	0.4385	-0.00473	0.01089

eTable 10: Full models for association between ZIP-level nutrition resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	28.1161	1.1836	<.0001	25.7958	30.4364
ZIP-level nutrition resources	-0.07146	0.03122	0.0234	-0.1331	-0.00980
ZIP-level afterschool resources	0.002639	0.02650	0.9208	-0.04967	0.05495
Age, years	-0.04949	0.002011	<.0001	-0.05344	-0.04555
Female	-1.3792	0.04395	<.0001	-1.4654	-1.2931
Race/ethnicity					
Asian/Multi/Other	-2.5116	0.09329	<.0001	-2.6944	-2.3287
Non-Hispanic Black	0.9650	0.09756	<.0001	0.7738	1.1562
Hispanic	0.7272	0.1081	<.0001	0.5152	0.9392
Non-Hispanic White	reference	n/a	n/a	n/a	n/a
Education					
College or >	-0.2787	0.07082	<.0001	-0.4175	-0.1399
High School Diploma	0.09695	0.07549	0.1991	-0.05102	0.2449
Less than High School Diploma	0.3870	0.09117	<.0001	0.2083	0.5657
Unknown/Declined	reference	n/a	n/a	n/a	n/a
Insurance					
Private	0.1858	1.0208	0.8555	-1.8150	2.1866
Medicare and Medicaid	0.06642	1.0240	0.9483	-1.9406	2.0735
Medicaid	0.6927	1.0215	0.4977	-1.3095	2.6948
Medicaid	-0.5000	1.0230	0.6250	-2.5050	1.5051
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.7143	0.09604	<.0001	0.5261	0.9026
History of Hypertension	2.7290	0.05550	<.0001	2.6202	2.8378
History of Coronary Heart Disease	-0.4139	0.08601	<.0001	-0.5825	-0.2453
History of Diabetes Mellitus	2.4211	0.07471	<.0001	2.2747	2.5676

eTable 10: Full models for association between ZIP-level nutrition resources and body mass index

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	0.5484	0.07350	<.0001	0.4044	0.6925
History of Osteoarthritis	1.3187	0.05467	<.0001	1.2115	1.4259
Charlson Comorbidity Score	0.06712	0.01268	<.0001	0.04227	0.09197
Clinic Visits	-0.00069	0.004383	0.8750	-0.00928	0.007900
Clinic Connectedness					
Connected to specific physician	0.3185	0.05024	<.0001	0.2200	0.4170
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.2529	0.1588	0.1113	-0.05838	0.5642
Lives in Area with Low Physical Food Access	0.1009	0.07792	0.1955	-0.05185	0.2536
Percentage of Area Living in Group Quarters	-0.00020	0.000060	0.0009	-0.00032	-0.00008
Lives in Area with Low Vehicle Access	0.1176	0.05585	0.0352	0.008130	0.2271
ZIP-level Unemployment Rate	0.2684	0.03881	<.0001	0.1921	0.3447
ZIP-level Median Household Income	-0.00001	1.972E-6	<.0001	-0.00002	-8.48E-6
ZIP-level Poverty Rate	-0.03270	0.01396	0.0199	-0.06020	-0.00521
ZIP-level Segregation	0.003113	0.003967	0.4332	-0.00470	0.01092

eTable 11: Full models for association between ZIP-level housing resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	115.70	11.1188	<.0001	93.9116	137.50
ZIP-level housing resources	-0.04612	0.05585	0.4106	-0.1567	0.06446
ZIP-level afterschool resources	-0.03286	0.04586	0.4755	-0.1240	0.05828
Age, years	0.1521	0.009429	<.0001	0.1337	0.1706
Female	-0.6839	0.1930	0.0004	-1.0622	-0.3055
Race/ethnicity					
Asian/Multi/Other	-1.2014	0.4952	0.0153	-2.1720	-0.2308
Non-Hispanic Black	2.8013	0.3960	<.0001	2.0251	3.5774
Hispanic	0.5064	0.5619	0.3675	-0.5950	1.6078
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	0.02428	0.3181	0.9392	-0.5992	0.6478
High School Diploma	0.1732	0.3236	0.5924	-0.4610	0.8074
Less than High School Diploma	0.6220	0.3914	0.1121	-0.1452	1.3893
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	8.3527	10.9765	0.4467	-13.1616	29.8671
Medicare and Medicaid	7.8728	10.9784	0.4733	-13.6453	29.3910
Medicaid	8.5660	10.9772	0.4352	-12.9499	30.0818
Medicaid	8.4728	10.9781	0.4402	-13.0447	29.9903
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.01463	0.4091	0.9715	-0.8165	0.7873
History of Coronary Heart Disease	-2.7190	0.2620	<.0001	-3.2325	-2.2055
History of Diabetes Mellitus	0.1079	0.2325	0.6426	-0.3478	0.5635
History of Depression	-0.9568	0.3076	0.0019	-1.5596	-0.3539

eTable 11: Full models for association between ZIP-level housing resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.5000	0.2009	0.0128	-0.8939	-0.1062
Charlson Comorbidity Score	-0.05959	0.04502	0.1856	-0.1478	0.02865
Clinic Visits	-0.02840	0.01601	0.0760	-0.05978	0.002975
Clinic Connectedness					
Connected to specific physician	-1.9594	0.2580	<.0001	-2.4651	-1.4538
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.2234	0.5896	0.7049	-0.9332	1.3799
Lives in Area with Low Physical Food Access	-0.6380	0.3321	0.0548	-1.2892	0.01327
Percentage of Area Living in Group Quarters	-0.00025	0.000262	0.3352	-0.00077	0.000261
Lives in Area with Low Vehicle Access	0.2689	0.2251	0.2324	-0.1725	0.7102
ZIP-level Unemployment Rate	0.1919	0.1055	0.0702	-0.01598	0.3998
ZIP-level Median Household Income	5.33E-7	4.993E-6	0.9151	-9.33E-6	0.000010
ZIP-level Poverty Rate	0.003603	0.03442	0.9168	-0.06460	0.07180
ZIP-level Segregation	-0.00127	0.01007	0.8999	-0.02117	0.01863

eTable 12: Full models for association between ZIP-level nutrition resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	115.52	11.1170	<.0001	93.7336	137.31
ZIP-level nutrition resources	0.01167	0.07270	0.8728	-0.1325	0.1559
ZIP-level afterschool resources	-0.06660	0.05852	0.2582	-0.1829	0.04971
Age, years	0.1522	0.009429	<.0001	0.1337	0.1707
Female	-0.6823	0.1930	0.0004	-1.0606	-0.3039
Race/ethnicity					
Asian/Multi/Other	-1.2077	0.4952	0.0147	-2.1782	-0.2371
Non-Hispanic Black	2.7981	0.3960	<.0001	2.0218	3.5744
Hispanic	0.5101	0.5622	0.3643	-0.5919	1.6120
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
education					
College or >	0.01868	0.3181	0.9532	-0.6048	0.6421
High School Diploma	0.1716	0.3236	0.5958	-0.4626	0.8059
Less than High School Diploma	0.6218	0.3915	0.1122	-0.1455	1.3891
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	8.3894	10.9765	0.4447	-13.1251	29.9038
Medicare and Medicaid	7.9053	10.9784	0.4715	-13.6130	29.4235
Medicaid	8.6004	10.9773	0.4334	-12.9155	30.1163
Medicaid	8.5087	10.9781	0.4383	-13.0089	30.0263
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.01592	0.4094	0.9690	-0.8183	0.7865
History of Coronary Heart Disease	-2.7161	0.2620	<.0001	-3.2295	-2.2026
History of Diabetes Mellitus	0.1087	0.2325	0.6399	-0.3469	0.5644
History of Depression	-0.9576	0.3076	0.0019	-1.5605	-0.3547

eTable 12: Full models for association between ZIP-level nutrition resources and systolic blood pressure

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.5002	0.2009	0.0128	-0.8940	-0.1063
Charlson Comorbidity Score	-0.05975	0.04502	0.1845	-0.1480	0.02849
Clinic Visits	-0.02845	0.01601	0.0756	-0.05982	0.002932
Clinic Connectedness					
Connected to specific physician	-1.9589	0.2580	<.0001	-2.4645	-1.4532
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.1603	0.5860	0.7845	-0.9893	1.3098
Lives in Area with Low Physical Food Access	-0.5789	0.3269	0.0768	-1.2201	0.06231
Percentage of Area Living in Group Quarters	-0.00025	0.000262	0.3343	-0.00077	0.000261
Lives in Area with Low Vehicle Access	0.2662	0.2251	0.2371	-0.1752	0.7076
ZIP-level Unemployment Rate	0.2065	0.1045	0.0493	0.000612	0.4124
ZIP-level Median Household Income	1.008E-6	4.966E-6	0.8395	-8.8E-6	0.000011
ZIP-level Poverty Rate	0.003660	0.03453	0.9158	-0.06473	0.07205
ZIP-level Segregation	-0.00086	0.01007	0.9325	-0.02075	0.01904

eTable 13: Full models for association between ZIP-level nutrition resources and low density lipoprotein cholesterol

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	103.76	38.1863	0.0066	28.9153	178.61
ZIP-level nutrition resources	0.09859	0.2309	0.6699	-0.3573	0.5545
ZIP-level afterschool resources	-0.00381	0.1854	0.9837	-0.3706	0.3630
Age, years	-0.3600	0.03023	<.0001	-0.4193	-0.3008
Female	11.7432	0.5645	<.0001	10.6367	12.8497
Race/ethnicity	0	.	.	.	.
Asian/Multi/Other	-2.6927	1.4423	0.0619	-5.5197	0.1343
Non-Hispanic Black	0.7350	1.2077	0.5428	-1.6323	3.1022
Hispanic	0.3468	1.7794	0.8455	-3.1409	3.8345
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1046	0.9328	0.9107	-1.9329	1.7237
High School Diploma	-0.2598	0.9497	0.7844	-2.1212	1.6016
Less than High School Diploma	-0.8496	1.1612	0.4644	-3.1256	1.4264
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	37.5148	37.8147	0.3212	-36.6052	111.63
Medicare and Medicaid	36.1970	37.8181	0.3385	-37.9296	110.32
Medicaid	37.4872	37.8163	0.3216	-36.6360	111.61
Medicaid	35.4040	37.8171	0.3492	-38.7206	109.53
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.6482	1.2438	0.6023	-1.7897	3.0861
History of Hypertension	-4.3457	1.1538	0.0002	-6.6072	-2.0842
History of Coronary Heart Disease	-14.8429	0.7275	<.0001	-16.2689	-13.4170
History of Diabetes Mellitus	-16.1429	0.6619	<.0001	-17.4404	-14.8455

eTable 13: Full models for association between ZIP-level nutrition resources and low density lipoprotein cholesterol

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	1.0979	0.9513	0.2485	-0.7668	2.9626
History of Osteoarthritis	1.0828	0.5853	0.0643	-0.06449	2.2302
Charlson Comorbidity Score	-0.9716	0.1366	<.0001	-1.2394	-0.7038
Clinic Visits	-0.1983	0.04901	<.0001	-0.2944	-0.1023
Clinic Connectedness					
Connected to specific physician	-1.4526	0.8446	0.0855	-3.1081	0.2029
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	-0.4909	1.7202	0.7754	-3.8649	2.8831
Lives in Area with Low Physical Food Access	0.2234	1.0117	0.8252	-1.7604	2.2073
Percentage of Area Living in Group Quarters	0.001870	0.000788	0.0177	0.000325	0.003414
Lives in Area with Low Vehicle Access	-1.1732	0.6607	0.0759	-2.4686	0.1222
ZIP-level Unemployment Rate	0.1519	0.3138	0.6287	-0.4659	0.7698
ZIP-level Median Household Income	-0.00001	0.000015	0.3460	-0.00004	0.000015
ZIP-level Poverty Rate	-0.06528	0.1068	0.5418	-0.2760	0.1454
ZIP-level Segregation	-0.00654	0.03045	0.8301	-0.06656	0.05347

eTable 14: Full models for association between ZIP-level substance abuse resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	7.0576	0.3362	<.0001	6.3986	7.7166
ZIP-level substance abuse resources	-0.00251	0.01460	0.8634	-0.03113	0.02611
ZIP-level afterschool resources	0.01106	0.007376	0.1336	-0.00339	0.02552
Age, years	-0.01059	0.001940	<.0001	-0.01440	-0.00679
Female	-0.1380	0.03843	0.0003	-0.2133	-0.06263
Race/ethnicity					
Asian/Multi/Other	-0.08503	0.08123	0.2952	-0.2443	0.07420
Non-Hispanic Black	0.07012	0.06209	0.2588	-0.05160	0.1918
Hispanic	0.06593	0.08944	0.4611	-0.1094	0.2413
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1646	0.06820	0.0158	-0.2983	-0.03090
High School Diploma	-0.01912	0.06665	0.7742	-0.1498	0.1116
Less than High School Diploma	-0.07235	0.07528	0.3366	-0.2200	0.07529
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	0.2134	0.05612	0.0001	0.1034	0.3234
Medicare and Medicaid	0.03459	0.05765	0.5486	-0.07842	0.1476
Medicaid	0.3912	0.06811	<.0001	0.2577	0.5247
Medicaid	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.1599	0.06505	0.0140	-0.2874	-0.03232
History of Hypertension	0.2365	0.05985	<.0001	0.1191	0.3538
History of Coronary Heart Disease	-0.03921	0.04940	0.4274	-0.1361	0.05764

eTable 14: Full models for association between ZIP-level substance abuse resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Depression	-0.03705	0.05766	0.5205	-0.1501	0.07598
History of Osteoarthritis	-0.1499	0.04010	0.0002	-0.2285	-0.07134
Charlson Comorbidity Score	0.01588	0.008146	0.0513	-0.00009	0.03185
Clinic Visits	0.006502	0.002846	0.0224	0.000922	0.01208
Clinic Connectedness					
Connected to specific physician	-0.08553	0.05430	0.1153	-0.1920	0.02092
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.3470	0.1270	0.0063	0.09804	0.5959
Lives in Area with Low Physical Food Access	-0.07748	0.06097	0.2039	-0.1970	0.04205
Percentage of Area Living in Group Quarters	-0.00001	0.000060	0.8418	-0.00013	0.000106
Lives in Area with Low Vehicle Access	0.04455	0.04429	0.3145	-0.04228	0.1314
ZIP-level Unemployment Rate	0.03710	0.01932	0.0549	-0.00078	0.07499
ZIP-level Median Household Income	1.636E-6	Unable to estimate	Unable to estimate	Unable to estimate	Unable to estimate
ZIP-level Poverty Rate	-0.00359	0.005890	0.5418	-0.01514	0.007953
ZIP-level Segregation	-0.00001	0.001802	0.9950	-0.00354	0.003522

eTable 15: Full models for association between ZIP-level mental health resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	7.0641	0.3371	<.0001	6.4033	7.7250
ZIP-level mental health resources	-0.00348	0.01130	0.7582	-0.02564	0.01868
ZIP-level afterschool resources	0.01159	0.006992	0.0974	-0.00212	0.02530
Age, years	-0.01058	0.001940	<.0001	-0.01438	-0.00678
Female	-0.1382	0.03843	0.0003	-0.2135	-0.06283
Race/ethnicity					
Asian/Multi/Other	-0.08415	0.08130	0.3007	-0.2435	0.07522
Non-Hispanic Black	0.07084	0.06217	0.2545	-0.05103	0.1927
Hispanic	0.06543	0.08946	0.4646	-0.1099	0.2408
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.1647	0.06820	0.0158	-0.2984	-0.03095
High School Diploma	-0.01936	0.06665	0.7715	-0.1500	0.1113
Less than High School Diploma	-0.07325	0.07536	0.3312	-0.2210	0.07454
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	0.2135	0.05612	0.0001	0.1035	0.3235
Medicare and Medicaid	0.03499	0.05767	0.5440	-0.07805	0.1480
Medicaid	0.3913	0.06810	<.0001	0.2578	0.5248
Medicaid	reference	n/a	n/a	n/a	n/a.
English is Primary Language	-0.1597	0.06502	0.0141	-0.2871	-0.03218
History of Hypertension	0.2365	0.05985	<.0001	0.1191	0.3538
History of Coronary Heart Disease	-0.03931	0.04940	0.4262	-0.1362	0.05753
History of Depression	-0.03699	0.05766	0.5212	-0.1500	0.07604

eTable 15: Full models for association between ZIP-level mental health resources and hemoglobin A1c

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
History of Osteoarthritis	-0.1498	0.04009	0.0002	-0.2284	-0.07123
Charlson Comorbidity Score	0.01585	0.008146	0.0518	-0.00012	0.03182
Clinic Visits	0.006518	0.002846	0.0220	0.000939	0.01210
Clinic Connectedness					
Connected to specific physician	-0.08559	0.05429	0.1150	-0.1920	0.02085
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	0.3477	0.1268	0.0061	0.09914	0.5962
Lives in Area with Low Physical Food Access	-0.07867	0.06091	0.1966	-0.1981	0.04074
Percentage of Area Living in Group Quarters	-0.00001	0.000060	0.8517	-0.00013	0.000107
Lives in Area with Low Vehicle Access	0.04534	0.04440	0.3072	-0.04169	0.1324
ZIP-level Unemployment Rate	0.03660	0.01940	0.0592	-0.00143	0.07462
ZIP-level Median Household Income	1.599E-6	Unable to estimate	Unable to estimate	Unable to estimate	Unable to estimate
ZIP-level Poverty Rate	-0.00359	0.005889	0.5423	-0.01513	0.007956
ZIP-level Segregation	-0.00002	0.001802	0.9931	-0.00355	0.003517

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	118.75	2.4411	<.0001	113.96	123.54
ZIP-level food resources	-0.08047	0.03550	0.0262	-0.1511	-0.00980
ZIP-level afterschool resources	0.06047	0.03336	0.0730	-0.00574	0.1267

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Age, years	0.1657	0.005420	<.0001	0.1550	0.1763
Female	-5.2802	0.1186	<.0001	-5.5126	-5.0477
Race/ethnicity					
Asian/Multi/Other	-2.6721	0.2363	<.0001	-3.1353	-2.2089
Non-Hispanic Black	0.6111	0.2706	0.0239	0.08082	1.1415
Hispanic	-0.7475	0.2728	0.0061	-1.2822	-0.2129
Non-Hispanic White	reference	n/a	n/a	n/a	n/a.
Education					
College or >	-0.02240	0.1940	0.9080	-0.4026	0.3577
High School Diploma	0.4658	0.2125	0.0284	0.04932	0.8823
Less than High School Diploma	0.9903	0.2550	0.0001	0.4905	1.4901
Unknown/Declined	reference	n/a	n/a	n/a	n/a.
Insurance					
Private	-4.3672	2.1456	0.0418	-8.5725	-0.1618
Medicare and Medicaid	-4.2024	2.1674	0.0525	-8.4505	0.04573
Medicaid	-4.6349	2.1479	0.0309	-8.8449	-0.4248
Medicaid	-2.2777	2.1596	0.2916	-6.5105	1.9551
Self-pay	reference	n/a	n/a	n/a	n/a.
English is Primary Language	0.9827	0.2700	0.0003	0.4536	1.5119
History of Depression	-0.1126	0.2130	0.5970	-0.5301	0.3048
History of Osteoarthritis	0.5132	0.1754	0.0034	0.1695	0.8570
Charlson Comorbidity Score	0.1840	0.04369	<.0001	0.09834	0.2696
Clinic Visits	-0.05715	0.01445	<.0001	-0.08548	-0.02882
Clinic Connectedness					
Connected to specific physician	-0.6938	0.1282	<.0001	-0.9450	-0.4425

eTable 16: Full models for association between ZIP-level food resources and systolic blood pressure in those without hypertension

	Estimate	Standard Error	p-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Connected to specific practice	reference	n/a	n/a	n/a	n/a.
Lives in Urban Area	-0.4004	0.3700	0.2793	-1.1261	0.3254
Lives in Area with Low Physical Food Access	0.2289	0.1896	0.2274	-0.1429	0.6006
Percentage of Area Living in Group Quarters	-0.00031	0.000146	0.0348	-0.00060	-0.00002
Lives in Area with Low Vehicle Access	-0.00646	0.1455	0.9646	-0.2917	0.2788
ZIP-level Unemployment Rate	0.2795	0.07224	0.0001	0.1373	0.4218
ZIP-level Median Household Income	-0.00002	3.286E-6	<.0001	-0.00002	-9.76E-6
ZIP-level Poverty Rate	-0.02364	0.02254	0.2968	-0.06835	0.02108
ZIP-level Segregation	0.01658	0.006771	0.0154	0.003208	0.02995

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3-4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			7-8
Study design	4	Present key elements of study design early in the paper	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-10
Bias	9	Describe any efforts to address potential sources of bias	10-13
Study size	10	Explain how the study size was arrived at	13
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10-13
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10-13
		(b) Describe any methods used to examine subgroups and interactions	10-13, technical appendix
		(c) Explain how missing data were addressed	10-13
		(d) If applicable, describe analytical methods taking account of sampling strategy	10-13
		(e) Describe any sensitivity analyses	10-13

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	13
		(b) Give reasons for non-participation at each stage	13
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13-14, table 1, tables 2-3
		(b) Indicate number of participants with missing data for each variable of interest	Tables 2-3
Outcome data	15*	Report numbers of outcome events or summary measures	14-15
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-15
		(b) Report category boundaries when continuous variables were categorized	n/a
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14-16, eappendix
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18-19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.