BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-025281
Article Type:	Research
Date Submitted by the Author:	09-Jul-2018
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, Venkataramani, Atheendar Reznor, Gally Fleegler, Eric; Children's Hospital Boston Atlas, Steven
Keywords:	SOCIAL MEDICINE, PRIMARY CARE, Hypertension < CARDIOLOGY, DIABETES & ENDOCRINOLOGY, Cardiac Epidemiology < CARDIOLOGY

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

Seth A. Berkowitz[1-3], Sanjay Basu[4,5], Atheendar Venkataramani[6,7], Gally Reznor[8], Eric W. Fleegler[9,10], Steven J. Atlas[8,9]

[1] Division of General Medicine and Clinical Epidemiology, Department of Medicine, University of North Carolina School of Medicine, Chapel Hill, NC

[2] The Cecil G. Sheps Center for Health Services Research, University of North Carolina at Chapel Hill, Chapel Hill, NC

[3] Center for Health Equity Research, Department of Social Medicine, University of North Carolina School of Medicine, Chapel Hill, NC

[4] Center for Primary Care and Outcomes Research, Center for Population Health Sciences, Departments of Medicine and of Health Research and Policy, Stanford University, Palo Alto, California

[5] Center for Primary Care, Harvard Medical School

[6] Department of Medical Ethics and Health Policy, Perelman School of Medicine, University of Pennsylvania, Philadelphia.

[7] Leonard Davis Institute of Health Economics, University of Pennsylvania, Philadelphia.

[8] Division of General Internal Medicine, Massachusetts General Hospital, Boston, Massachusetts

[9] Harvard Medical School, Boston, Massachusetts

[10] Division of Emergency Medicine, Boston Children's Hospital, Boston, Massachusetts

Corresponding Author and Request for Reprints:

Seth A. Berkowitz, MD MPH

5034 Old Clinic Bldg

CB 7110

Chapel Hill, NC 27599

Tel: 919-966-2276

seth_berkowitz[at]med.unc.edu

Tables: 3

Figures: 1

Word Count

Abstract: 267/300

Manuscript: 2991/4000

Running Title: Social Service Resources and Cardiometabolic Risk

Key Words: cardiovascular disease, food insecurity, health disparities, socioeconomic status

Objectives: Interest in linking patients with unmet social needs to area-level resources, such as food pantries and employment centers, is growing. However, whether the presence of these resources is associated with better health outcomes is unclear. We sought to determine if area-level resources are associated with lower levels of cardiometabolic risk factors.

Design: Cross-sectional.

Setting: Data were collected in a primary care network in eastern Massachusetts in 2015.

Participants and Primary and Secondary Outcome Measures: 123,355 participants were included. The primary outcome was body mass index (BMI). The secondary outcomes were systolic blood pressure (SBP), low density lipoprotein cholesterol (LDL), and hemoglobin a1c (HbA1c). All participants were included in BMI analyses. Participants with hypertension were included in SBP analyses. Participants with an indication for cholesterol lowering were included in LDL analyses, and participants with diabetes mellitus were included in HbA1c analyses. We used a random forest-based machine-learning algorithm to identify types of resources associated with study outcomes. We then tested the association of selected resources with these outcomes, using multi-level models to account for individual-level, clinic-level, and other area-level factors.

Results: Resources associated with lower BMI included more food resources (-0.08 kg/m^2 per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m^2), employment resources (-0.05 kg/m^2, 95%CI -0.11 to -0.002 kg/m^2), and nutrition

resources (-0.07 kg/m^2, 95%CI -0.13 to -0.01 kg/m^2). No area resources were associated with differences in SBP, LDL, or HbA1c.

Conclusions: Access to specific local resources is associated with better BMI. Efforts to link patients to area resources, and to improve the resources landscape within communities, may help reduce BMI and improve population health.

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

Cardiometabolic disease remains the most common cause of morbidity and mortality in the U.S.[1] Though better control of cardiometabolic risk factors could substantially reduce this morbidity and mortality, individuals with low socioeconomic status (SES) are less likely to achieve recommended goals.[2] Among the reasons for this are unmet basic needs, including such factors as food insecurity, housing instability, and lack of transportation. These unmet needs have been associated with higher levels of important cardiometabolic risk factors including increased body mass index (BMI), systolic blood pressure (SBP), low density lipoprotein cholesterol (LDL), and hemoglobin A1c (HbA1c), even after adjusting for factors like race/ethnicity, income, and education.[3–8]

Healthcare systems are increasingly interested in working with community partners to help link their patients to local resources, such as food pantries or housing agencies, to help meet these social needs.[9–13] This approach is exemplified by the Accountable Health Communities initiative from the Centers for Medicare & Medicaid Services, which involves screening for adverse social circumstances and linking those who screen positive to community resources.[14] However, there remain significant gaps in knowledge regarding such approaches. Critically, healthcare systems need to know which organizations to partner with, and potentially what types of resources to invest in.[15] This is especially true as the connection between resource type and need may not always be straightforward. For example, a food pantry could help alleviate food insecurity, but so could employment. Further, the relationship between specific health conditions and area-resources needs further

study. Aspects of some conditions, such as HbA1c in those with diabetes mellitus, may be more amenable to intensive clinical management. Others, such as BMI, may have less effective treatment options within the healthcare system. Therefore, the role that area resources play may differ depending on the intensity and impact of concurrent clinical management. This distinction is important both for population health, and for healthcare systems trying to decide where to invest in order meet population health metrics that cannot easily be achieved through clinical care alone.

To help address these issues, and inform further interventions, we sought to study associations between area-resources and cardiometabolic risk factors in a large primary care network. Our goal was to understand which resource types were associated with improved levels of BMI, SBP, LDL, and HbA1c, and to determine whether area-resources had stronger associations with cardiometabolic risk factors for conditions that are less amenable to clinical management.

Methods

Setting and Study Sample

Data for this study came from two primary sources: an asset mapping of community resources, and electronic health records. The asset mapping came from the HelpSteps database, a comprehensive asset mapping of area-resources in eastern Massachusetts maintained by the Mayor's Health Line at the Boston Public Health Commission and Boston Children's Hospital.[16] The clinical records came from a primary care network in eastern Massachusetts, a network of 18 primary care

practices, including hospital-based, academic, and community health center sites. All adult (age ≥ 18 years) primary care patients seen between January 1, 2012 and December 31, 2015 were included. Data were current on December 31, 2015. The most recent patient address was geocoded for the study. Patients without available addresses were excluded—prior work has shown that only 0.15% of patients in this cohort could not be geocoded.[17]

The Partners Healthcare Human Research Committee exempted this analysis of secondary data without patient contact from IRB review.

Patient and Public Involvement

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

Area Resources

The HelpSteps database contains information on area-resources across 16 non-mutually exclusive domains: health, housing, food (e.g. food pantries), employment, violence, safety, substance abuse, mental health, education, parenting, nutrition (e.g. nutrition counseling), after school, sexual health, transportation, diabetes, and care transitions. Agencies providing multiple resources could be included in more than

one domain. Area-resources were also geocoded, and then counts of resources for each domain were calculated at 4 geographic levels in roughly increasing order of size: census tract (using U.S. Census 2010 boundaries), ZIP code tabulation area (which we refer to throughout this paper as 'ZIP' level, owing to common use of the term, again using U.S Census 2010 boundaries), 'neighborhood' (e.g. Allston, Roxbury, a designation based on Boston city planning that may better capture actual movement patterns), and county.

Clinical Outcomes

To assess clinical outcomes, we calculated the mean of all values recorded in 2015 from individual's electronic health record for the following measurements: body mass index (in kg/m^2), systolic blood pressure (in mm Hg), low-density lipoprotein cholesterol (in mg/dL) and HbA1c (%). All values were obtained in the process of usual care.

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 algorithm[18], 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.[19,20]

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 understand the relationship that specific geographic levels and resource types had with clinical outcomes. To avoid multiple hypothesis testing that may lead to the identification of spurious associations, we employed a machine learning technique called variable selecting using random forest (VSURF) to screen through variables in the derivation set.[21,22] This was done using a derivation dataset, which consisted of a random partition of the entire dataset. Finally, we used multi-level modeling in the test set (not used in the derivation stage) to test a small number of candidate variables identified by VSURF as being most important to explaining variations in

the derivation set. VSRUF is described in more detail in the technical appendix and eFigure 1.

Multi-level modeling

In the test dataset, we fit multi-level linear mixed models to test the association between variables identified in the VSURF step and the outcome of interest. The BMI model included all study participants. The SBP model included those with a diagnosis of hypertension. The LDL model included those with common diagnoses (hypertension, diabetes, coronary heart disease, cerebrovascular disease, congestive heart failure) where LDL lowering is most beneficial. The HbA1c models included those with a diagnosis of diabetes. 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.

Falsification tests

To reduce the possibility that observed associations due to other unmeasured characteristics of the area, rather than the specific area resource tested, we also

conducted falsification analyses. To do this, we used the same modeling approach as above, but tested for the association between area after school resources for children and the outcome of interest. Our reasoning was that, since there was unlikely to be any direct effect of after school resources on adult health, any observed association would be due to unmeasured area-characteristics not appropriately adjusted for in our model (such as high levels of civic engagement or community organization, or other beneficial resources).

Variations in clinical management

To help explore whether variations in the intensity of clinical management could explain whether community resources were associated with health outcomes, we also used the above modeling approach to test whether area resources were associated with SBP in those *without* a diagnosis of hypertension. The primary care network in the study has quality improvement program that emphasize the importance of SBP, LDL, and HbA1c control in appropriate clinical populations. Since BMI (in any population) and SBP control in those without a diagnosis of hypertension are not included in these programs, we reasoned that area-resources may be more important when clinicians are not intensively attempting to impact an outcome. We focused on BMI and systolic blood pressure among those *without* hypertension for this because BMI and SBP are routinely measured at all practice visits for all patients.

Because of its mechanistically plausible relationship with BMI, we used the association between ZIP-level food resources and BMI as the primary outcome, with secondary analyses being the associations between other VSURF selected area-resources and clinical outcomes.

Robustness checks

In addition to the main analyses, we conducted a series of robustness checks that examined whether different specifications of resources in the area (e.g. resources per capita or resources per capita living in poverty) or different functional forms (e.g. including polynomial terms or using splines) would alter the observed associations between area-level resources and outcomes. We also conducted analyses restricted to those with indicators of lower socioeconomic status (high school diploma or lower educational attainment, living in a ZIP where > 15% of individuals are in poverty) to ensure the results were applicable to those most likely to utilize the resources studied.

A p-value of < 0.05 was taken to indicate statistical significance. Analyses were conducted in SAS Version 9.4 (Cary, NC), Stata 14 (College Station, TX), and R version 3.3.4 (Vienna, Austria).

Results

Overall, 123,355 participants were included in the study. All participants were eligible for the BMI analyses. Based on inclusion criteria, 43,509 were included in the hypertension analyses, 46,940 were included in the LDL analyses, and 13,127 were included in the diabetes analyses. Demographic characteristics of the overall sample are presented in Table 1. Demographic characteristics of the samples used in the hypertension, LDL cholesterol, and diabetes analyses are presented in eTables 1-3. Overall, the mean age was 52.4 (SD 16.9) years, the sample was 41.5% male, 82.1% non-Hispanic white, 5.8% non-Hispanic black, and 6.5% Hispanic. The median number of years participants were followed in our network was 9 (intraquartile range (IQR): 3, 10), and the median number change of address per year followed was 0.1 (IQR 0.1, 0.25), suggesting that participants resided at their current address for the majority of their time in our network.

In general, individuals living in areas with more resources were less well-off (eTable 4). Maps depicting the distribution of the resources are presented in Figure 1 and eFigures 2-3.

The mean BMI in the sample was 27.8 (SD 6.2) kg/m^2. In the hypertension analyses, the mean BP was 131.6 (SD 15.8) mmHg. In the LDL analyses, the mean LDL was 102.9 (SD 39.8) mg/dL, and in the diabetes analyses the mean HbA1c was 7.1 (SD 1.5)%.

Among geographic levels assessed, all resources selected were at the ZIP level (Table 2). For the BMI analyses, the selected resources were ZIP level food resources, ZIP level employment resources, and ZIP level nutrition resources. For hypertension analyses, the selected resources were ZIP housing and ZIP nutrition resources. For LDL analyses, the only selected resource was ZIP nutrition resources. For diabetes analyses, the selected resources were ZIP mental health and ZIP substance use resources.

For the BMI analyses, we tested the association between selected resources and BMI, adjusting for the factors described in the statistical analysis section, and accounting for clustering at the clinic and ZIP level with multi-level linear mixed models. We found that resources associated with lower BMI included more food resources (-0.08 kg/m^2 per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m^2, p= .001), employment resources (-0.05 kg/m^2, 95%CI -0.11 to -0.002 kg/m^2, p=.04), and nutrition resources (-0.07 kg/m^2, 95%CI -0.13 to -0.01 kg/m^2, p=.02) (full models for these and all robustness checks in eAppendix tables 5-16). Table 3 compares mean BMI and obesity prevalence at selected numbers of resources, adjusted for the other factors in the model. For example, the mean BMI in neighborhoods with the median (0) number of food resources was 27.8 kg/m^2, while the mean BMI in neighborhoods in the 75^{th} percentile (3 resources) was 27.5 kg/m^2, and the 90^{th} percentile (8 resources) was 27.1 kg/m^2. Falsification tests found the expected lack of association between afterschool resources and BMI (p=.67).

Robustness checks found that our results did not vary substantially with other specifications of area-level resources (eTables 5-7).

In the hypertension analyses, neither housing resources (-0.05 mm Hg per additional resource, 95%CI -0.16 to 0.06 mm Hg, p=.41) nor nutrition resources (0.01 mm Hg, 95%CI -0.13 to 0.16 mm Hg, p=.87) were associated with systolic blood pressure after adjustment for individual level and area level characteristics. In LDL analyses, nutrition resources (0.10 mg/dL per additional resource, 95%CI -0.36 to 0.55 mg/dL, p=.67) were not associated with LDL cholesterol in adjusted models. In diabetes analyses, neither substance abuse resources (-0.003% per additional resource, 95%CI -0.03 to 0.02%, p=.86) nor mental health resources were associated with HbA1c (-0.003 %, 95%CI -0.03 to 0.02%, p=.76).

In analyses looking at systolic blood pressure among those without a diagnosis of hypertension (i.e., those with no reason for clinical management of blood pressure), food resources were associated with lower systolic blood pressure in linear mixed models adjusted for the same factors as above (-0.08 mm Hg per additional resource, 95%CI -0.15 to -0.01 mm Hg, p=.03). Mean systolic blood pressure was approximately 1 mm Hg lower at the 95th percentile (118.9 mm Hg) of food resources compared with the 50th percentile (119.8 mm Hg).

Full models for all analyses are presented in eTables 8-16.

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/m^2 difference in BMI between individuals in a well-resourced versus poorly resourced ZIP is similar to the 0.6 increase kg/m^2 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

plausibly support health, such as food and nutrition resources, would be associated with lower cardiometabolic risk.

The positive and negative associations between community resources and cardiometabolic risk factors may have important public health implications. The association between increased area resources and lower BMI suggests that efforts to help link patients to community resources, and to help improve the resources landscape within communities, may be a successful strategy for improving population health, particularly for risk factors such as BMI where clinical management may not be prioritized.[10,11,27] This is reinforced by the finding that SBP, among those without hypertension, is lower in those living in areas with more resources. Since SBP does not come under clinical management for those without hypertension, this finding supports the potential for area resources to impact population health, and is consistent with guidelines that recommend lifestyle, rather than pharmacologic, approaches to pre-hypertension treatment.[28] Future work in this area should investigate whether interventions that link individuals to area resources show clinical benefits.

Our finding should be interpreted in light of several limitations. We did not have access to data regarding use of the resources. However, we did employ a multi-level modeling framework, consisting of both individual-level and area-level measurement, to avoid issues of ecologic fallacy. Next, our study was cross-sectional, and thus we cannot establish time-ordering between the exposure and the

cardiometabolic outcomes. However, we think it is less likely that lower BMI would drive individuals into areas with more resources than vice versa, as areas with higher resources tended to have other adverse features, such as lower income and higher poverty, which are likely more salient considerations for those choosing where to live. Finally, because of the relatively high residential stability within this primary care population, we only examined the association between current area of residence and the study outcomes. However, for those who do move, this could lead to misclassification, which would tend to bias results to the null. These limitations are balanced by several strengths. We had access to a detailed mapping of area resources, along with detailed individual-level health information. Further, in addition to the multi-level framework we used, the use of falsification tests demonstrated that unadjusted area-level factors are not likely to explain the observed results.

In summary, ZIP-level food, employment, and nutrition resources were associated with BMI differences that were clinically meaningfully and statistically significant. Further, the association between area resources and cardiometabolic risk factors differed based on the specific risk factor. Investing in area resources and linkage programs may be an important way to help reduce cardiometabolic risk for vulnerable individuals, especially for situations not under intensive clinical management.

Acknowledgements

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.

Funding Statement: Research reported in this publication was supported by the National Institute for Diabetes and Digestive and Kidney Disease of the National Institutes of Health, and the National Institute on Minority Health and Health Disparities of the National Institutes of Health under Award Numbers DP2MD010478 (SB), U54MD010724 (SB), and K23DK109200 (SAB). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Author Contribution List: SAB conducted the data analysis, wrote the first draft of the manuscript, and is the guarantor of the article. SAB, EWF, and SJA conceived of the study. GR assisted with data analysis. SB, AV, and GR contributed to interpretation of results and critical revision of the manuscript for intellectual context. All authors (SAB, SB, AV, GR, EF, and SJA) read and approved the final manuscript for submission.

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

References

1. Centers for Disease Control and Prevention. Deaths and Mortality. https://www.cdc.gov/nchs/fastats/deaths.htm. Published March 5, 2018. Accessed March 19, 2018.

2. Havranek EP, Mujahid MS, Barr DA, et al. Social Determinants of Risk and Outcomes for Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Circulation*. 2015;132(9):873-898. doi:10.1161/CIR.0000000000000228

3. Berkowitz SA, Baggett TP, Wexler DJ, Huskey KW, Wee CC. Food insecurity and metabolic control among U.S. adults with diabetes. *Diabetes Care*. 2013;36(10):3093-3099. doi:10.2337/dc13-0570

4. Berkowitz SA, Meigs JB, DeWalt D, et al. Material need insecurities, control of diabetes mellitus, and use of health care resources: results of the Measuring Economic Insecurity in Diabetes study. *JAMA Intern Med*. 2015;175(2):257-265. doi:10.1001/jamainternmed.2014.6888

5. Berkowitz SA, Berkowitz TSZ, Meigs JB, Wexler DJ. Trends in food insecurity for adults with cardiometabolic disease in the United States: 2005-2012. *PloS One*. 2017;12(6):e0179172. doi:10.1371/journal.pone.0179172

6. Seligman HK, Laraia BA, Kushel MB. Food insecurity is associated with chronic disease among low-income NHANES participants. *J Nutr*. 2010;140(2):304-310. doi:10.3945/jn.109.112573

7. Baer TE, Scherer EA, Richmond TK, Fleegler EW, Hassan A. Food Insecurity, Weight Status, and Perceived Nutritional and Exercise Barriers in an Urban Youth Population. *Clin Pediatr (Phila)*. 2018;57(2):152-160. doi:10.1177/0009922817693301

8. Morales ME, Berkowitz SA. The Relationship Between Food Insecurity, Dietary Patterns, and Obesity. *Curr Nutr Rep*. 2016;5(1):54-60. doi:10.1007/s13668-016-0153-y

9. Hassan A, Blood EA, Pikcilingis A, et al. Youths' health-related social problems: concerns often overlooked during the medical visit. *J Adolesc Health Off Publ Soc Adolesc Med*. 2013;53(2):265-271. doi:10.1016/j.jadohealth.2013.02.024

10. Hassan A, Scherer EA, Pikcilingis A, et al. Improving Social Determinants of Health: Effectiveness of a Web-Based Intervention. *Am J Prev Med*. 2015;49(6):822-831. doi:10.1016/j.amepre.2015.04.023

11. Berkowitz SA, Hulberg AC, Standish S, Reznor G, Atlas SJ. Addressing Unmet Basic Resource Needs as Part of Chronic Cardiometabolic Disease Management. *JAMA Intern Med*. 2017;177(2):244-252. doi:10.1001/jamainternmed.2016.7691

12. Gottlieb LM, Wing H, Adler NE. A Systematic Review of Interventions on Patients' Social and Economic Needs. *Am J Prev Med*. July 2017. doi:10.1016/j.amepre.2017.05.011

13. Gottlieb LM, Hessler D, Long D, et al. Effects of Social Needs Screening and In-Person Service Navigation on Child Health: A Randomized Clinical Trial. *JAMA Pediatr*. 2016;170(11):e162521. doi:10.1001/jamapediatrics.2016.2521

14. Alley DE, Asomugha CN, Conway PH, Sanghavi DM. Accountable Health Communities--Addressing Social Needs through Medicare and Medicaid. *N Engl J Med*. 2016;374(1):8-11. doi:10.1056/NEJMp1512532

15. Bauer SR, Monuteaux MC, Fleegler EW. Geographic Disparities in Access to Agencies Providing Income-Related Social Services. *J Urban Health Bull N Y Acad Med*. 2015;92(5):853-863. doi:10.1007/s11524-015-9971-2

16. Fleegler E, J. Bottino C, Pikcilingis A, Baker B, Kistler E, Hassan A. Referral System Collaboration Between Public Health and Medical Systems: A Population Health Case Report. *Natl Acad Med Perspect Popul Health Case Rep*. May 2016.

17. Berkowitz SA, Traore CY, Singer DE, Atlas SJ. Evaluating area-based socioeconomic status indicators for monitoring disparities within health care systems: results from a primary care network. *Health Serv Res*. 2015;50(2):398-417. doi:10.1111/1475-6773.12229

18. Atlas SJ, Grant RW, Ferris TG, Chang Y, Barry MJ. Patient-physician connectedness and quality of primary care. *Ann Intern Med*. 2009;150(5):325-335.

19. USDA Food Access Research Atlas Documentation. https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/. Accessed August 11, 2017.

20. Napierala J, Denton N. Measuring Residential Segregation With the ACS: How the Margin of Error Affects the Dissimilarity Index. *Demography*. 2017;54(1):285-309. doi:10.1007/s13524-016-0545-z

21. Genuer R, Poggi J-M, Tuleau-Malot C. Variable Selection Using Random Forests. *Pattern Recogn Lett*. 2010;31(14):2225–2236. doi:10.1016/j.patrec.2010.03.014

22. Genuer R, Poggi J-M, Tuleau-Malot C. VSURF: An R Package for Variable Selection Using Random Forests. *R J*. 2015;7(2):19-33.

23. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *The Lancet*. 2016;387(10026):1377-1396. doi:10.1016/S0140-6736(16)30054-X

24. Thomas AJ, Eberly LE, Davey Smith G, Neaton JD, Stamler J. Race/Ethnicity, Income, Major Risk Factors, and Cardiovascular Disease Mortality. *Am J Public Health*. 2005;95(8):1417-1423. doi:10.2105/AJPH.2004.048165

25. Diez Roux AV. Investigating Neighborhood and Area Effects on Health. *Am J Public Health*. 2001;91(11):1783-1789. doi:10.2105/AJPH.91.11.1783

26. Kelli HM, Hammadah M, Ahmed H, et al. Association Between Living in Food Deserts and Cardiovascular Risk. *Circ Cardiovasc Qual Outcomes*. 2017;10(9):e003532. doi:10.1161/CIRCOUTCOMES.116.003532

27. Garg A, Toy S, Tripodis Y, Silverstein M, Freeman E. Addressing social determinants of health at well child care visits: a cluster RCT. *Pediatrics*. 2015;135(2):e296-304. doi:10.1542/peds.2014-2888

28. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. January 2017:HYP.0000000000000065. doi:10.1161/HYP.0000000000000065

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.

Table 2: Distribution of Selected Resources

BMI Analyses							
Resource*	Minimum	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th 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/m^2, 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

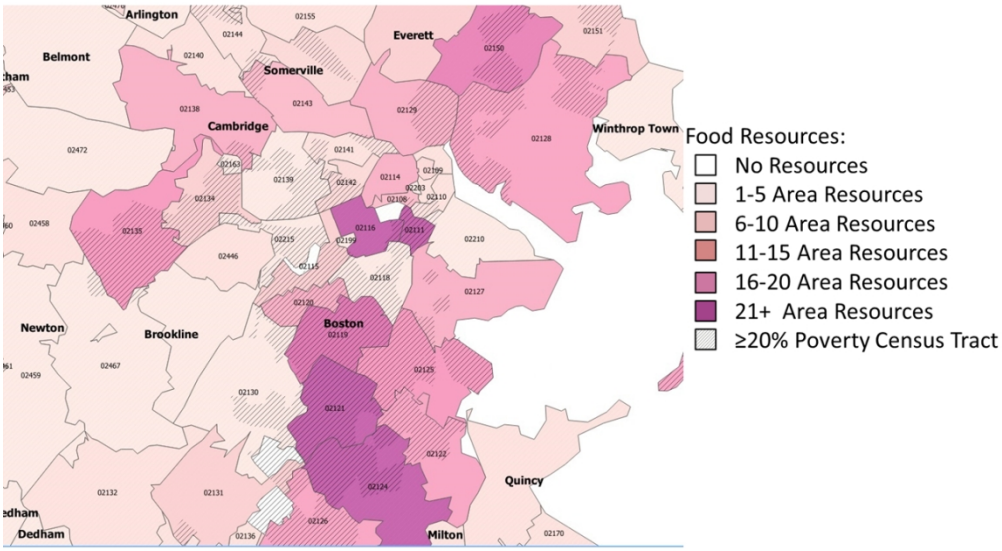


Figure 1

338x190mm (96 x 96 DPI)

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

Technical Appendix

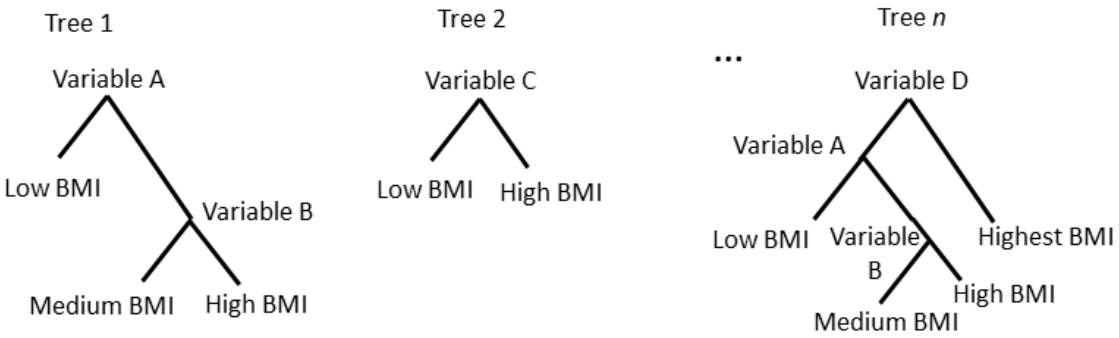
VSURF

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

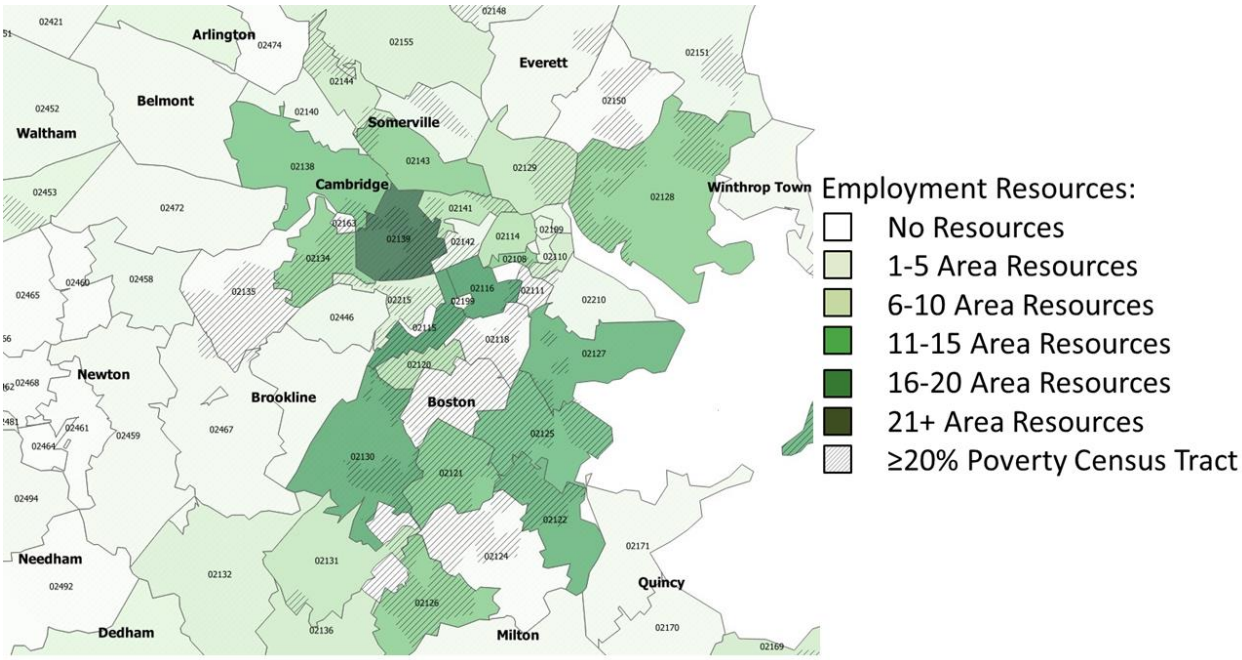
significance testing is not used in the selection of variables, unlike p-value-based selection algorithms.

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

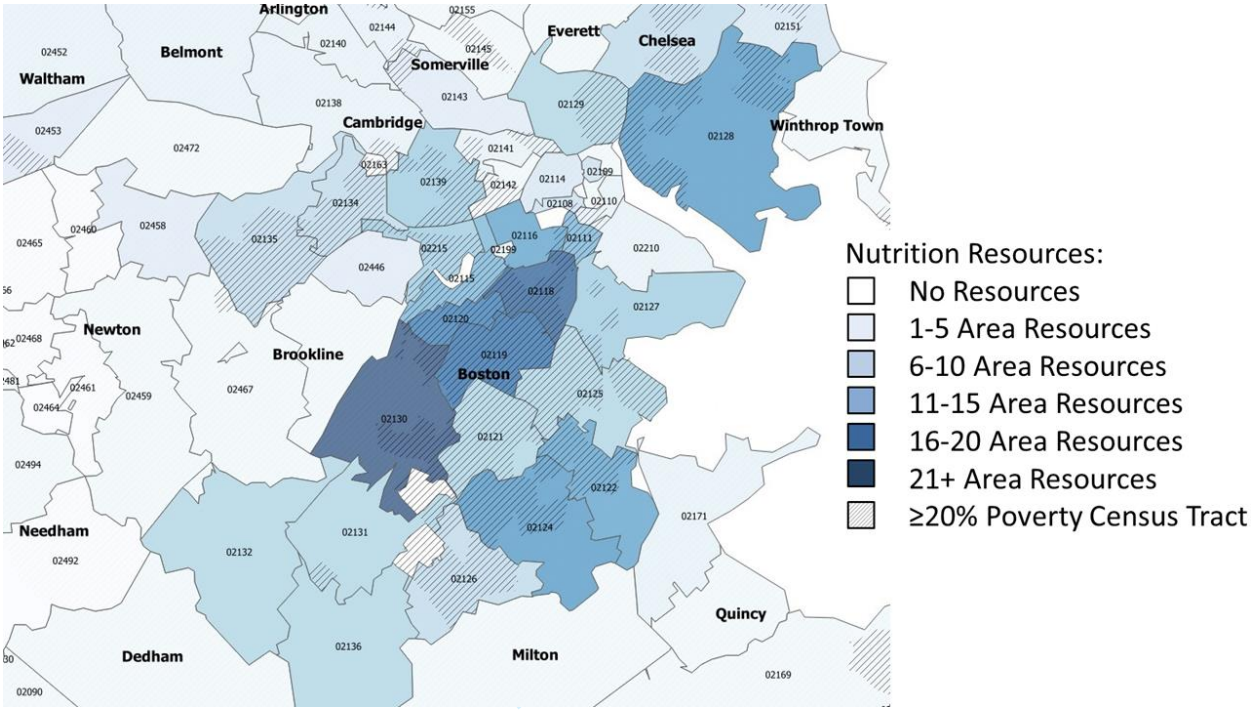


From a random subset of variables and a bootstrap resample of individuals in the derivation cohort, a decision tree that optimally splits the sample is created. This process is repeated in a second bootstrap resample with a second randomly selected subset of variables, and so on until *n* trees (n=2000 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



eFigure 3: Nutrition Resources by ZIP



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)

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)

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)

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

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)

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-025281.R1
Article Type:	Research
Date Submitted by the Author:	13-Dec-2018
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
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	General practice / Family practice, Health services research, Public health
Keywords:	SOCIAL MEDICINE, PRIMARY CARE, Hypertension < CARDIOLOGY, DIABETES & ENDOCRINOLOGY, Cardiac Epidemiology < CARDIOLOGY

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

Seth A. Berkowitz[1-3], Sanjay Basu[4,5], Atheendar Venkataramani[6,7], Gally Reznor[8], Eric W. Fleegler[9,10], Steven J. Atlas[8,9]

[1] Division of General Medicine and Clinical Epidemiology, Department of Medicine, University of North Carolina School of Medicine, Chapel Hill, NC

[2] The Cecil G. Sheps Center for Health Services Research, University of North Carolina at Chapel Hill, Chapel Hill, NC

[3] Center for Health Equity Research, Department of Social Medicine, University of North Carolina School of Medicine, Chapel Hill, NC

[4] Center for Primary Care and Outcomes Research, Center for Population Health Sciences, Departments of Medicine and of Health Research and Policy, Stanford University, Palo Alto, California

[5] Center for Primary Care, Harvard Medical School

[6] Department of Medical Ethics and Health Policy, Perelman School of Medicine, University of Pennsylvania, Philadelphia.

[7] Leonard Davis Institute of Health Economics, University of Pennsylvania, Philadelphia.

[8] Division of General Internal Medicine, Massachusetts General Hospital, Boston, Massachusetts

[9] Harvard Medical School, Boston, Massachusetts

[10] Division of Emergency Medicine, Boston Children's Hospital, Boston, Massachusetts

Corresponding Author and Request for Reprints:

Seth A. Berkowitz, MD MPH

5034 Old Clinic Bldg

CB 7110

Chapel Hill, NC 27599

Tel: 919-966-2276

seth_berkowitz@med.unc.edu

Tables: 3

Figures: 1

Word Count

Abstract: 299/300

Manuscript: 3341/4000

Running Title: Social Service Resources and Cardiometabolic Risk

Key Words: cardiovascular disease, food insecurity, health disparities, socioeconomic status

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

Design: Cross-sectional.

Setting: Data were collected in a primary care network in eastern Massachusetts in 2015.

Participants and Primary and Secondary Outcome Measures: 123,355 participants were included. The primary outcome was body mass index (BMI). The secondary outcomes were systolic blood pressure (SBP), low density lipoprotein cholesterol (LDL), and hemoglobin A1c (HbA1c). All participants were included in BMI analyses. Participants with hypertension were included in SBP analyses. Participants with an indication for cholesterol lowering were included in LDL analyses, and participants with diabetes mellitus were included in HbA1c analyses. We used a random forest-based machine-learning algorithm to identify types of resources associated with study outcomes. We then tested the association of ZIP-level selected resource types (three for BMI, two each for SBP and HbA1c analyses, and one for LDL analyses) with these outcomes, using multi-level models to account for individual-level, clinic-level, and other area-level factors.

Results: Resources associated with lower BMI included more food resources (-0.08 kg/m^2 per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m^2),

employment resources (-0.05 kg/m^2, 95%CI -0.11 to -0.002 kg/m^2), and nutrition resources (-0.07 kg/m^2, 95%CI -0.13 to -0.01 kg/m^2). No area resources were associated with differences in SBP, LDL, or HbA1c.

Conclusions: Access to specific local resources is associated with better BMI. Efforts to link patients to area resources, and to improve the resources landscape within communities, may help reduce BMI and improve population health.

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

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

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

particular health-related need may not be straightforward. For example, a food pantry could help alleviate food insecurity, but so could employment.

To help address these issues, and inform further interventions, we sought to study associations between area resources and cardiometabolic risk factors in a large primary care network. Our goal was to understand which resource types were associated with improved levels of BMI, SBP, LDL, and HbA1c, and to determine whether area resources had stronger associations with cardiometabolic risk factors for conditions that are less amenable to clinical management.

Methods

Setting and Study Sample

Data for this study came from two primary sources: an asset mapping of community resources, and electronic health records. The asset mapping came from the HelpSteps database, a comprehensive asset mapping of area resources in eastern Massachusetts.[19] The clinical records came from a primary care network in eastern Massachusetts, a network of 18 primary care practices, including hospital-based, academic, and community health center sites. All adult (age ≥ 18 years) primary care patients seen between January 1, 2012 and December 31, 2015 were included. Data were current on December 31, 2015. The most recent patient address was geocoded for the study. Patients without available addresses were excluded—prior work has shown that only 0.15% of patients in this cohort could not be geocoded.[20]

The Partners Healthcare Human Research Committee exempted this analysis of secondary data without patient contact from IRB review.

Patient and Public Involvement

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

Area Resources

HelpSteps (www.helpsteps.com) is a web and mobile screening and referral system for social needs. Originally launched in 2010, the system uses a database of social services throughout the greater Boston area to connect families to appropriate services. The database is maintained in collaboration between Boston Children's Hospital and the Mayor's Health Line at the Boston Public Health Commission. Every agency is contacted at least once per year to maintain the accuracy of the data and to grow the database. HelpSteps contains information on area resources across 16 non-mutually exclusive domains: health, housing, food employment, violence, safety, substance abuse, mental health, education, parenting, nutrition, after school, sexual health, transportation, diabetes, and care transitions. An example of organizations that would be in the food domain are food pantries. The employment domain would consist of job placement or job training services. And the nutrition

domain would include organizations that provide food counseling. Agencies providing multiple resources could be included in more than one domain. Because individual-level data for this study came from 2015, we used information from HelpSteps that was current as of 2015. For this study, 'area resources' are defined as the number of organizations found in the HelpSteps database providing assistance for a given domain and within a given geographic area.

After geocoding the addresses for both individuals and the area resource organization, we created counts, for each individual, of how many resources for each domain were within the same geographic area as they were. We did this at 4 geographic levels in roughly increasing order of size: census tract (using U.S. Census 2010 boundaries), ZIP code tabulation area (which we refer to throughout this paper as 'ZIP' level, owing to common use of the term, again using U.S Census 2010 boundaries), 'neighborhood' (e.g. Allston, Roxbury, a designation based on Boston city planning that may better capture actual movement patterns), and county.

Clinical Outcomes

To assess clinical outcomes, we calculated the mean of all values recorded in 2015 from individual's electronic health record for the following measurements: body mass index (in kg/m^2), systolic blood pressure (in mm Hg), low-density lipoprotein cholesterol (in mg/dL) and HbA1c (%). All values were obtained in the process of usual care.

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 algorithm[21], 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 understand the relationship that specific geographic levels and resource types had

with clinical outcomes. Because the nested structure of our data violate the statistical independence assumption that underlies parametric, regression-based variable selection approaches (such as forward, backward, or step-wise selection), and to avoid multiple hypothesis testing that may lead to the identification of spurious associations, we employed a non-parametric machine learning technique called variable selecting using random forest (VSURF) to screen through variables in the derivation set.[24,25] This was done using a derivation dataset, which consisted of a random partition of the entire dataset. Finally, we used multi-level modeling in the test set (not used in the derivation stage) to test a small number of candidate variables identified by VSURF as being most important to explaining variations in the derivation set. VSRUF is described in more detail in the technical appendix and eFigure 1.

Multi-level modeling

In the test dataset, we fit multi-level linear mixed models to test the association between variables identified in the VSURF step and the outcome of interest. The BMI model included all study participants. The SBP model included those with a diagnosis of hypertension. The LDL model included those with common diagnoses (hypertension, diabetes, coronary heart disease, cerebrovascular disease, congestive heart failure) where LDL lowering is most beneficial. The HbA1c models included those with a diagnosis of diabetes. 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.

Falsification tests

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

Variations in clinical management

To help explore whether variations in the intensity of clinical management could explain whether community resources were associated with health outcomes, we also used the above modeling approach to test whether area resources were associated with SBP in those *without* a diagnosis of hypertension. The primary care

network in the study has quality improvement program that emphasize the importance of SBP, LDL, and HbA1c control in appropriate clinical populations. Since BMI (in any population) and SBP control in those without a diagnosis of hypertension are not included in these programs, we reasoned that area resources may be more important when clinicians are not intensively attempting to impact an outcome. We focused on BMI and systolic blood pressure among those *without* hypertension for this because BMI and SBP are routinely measured at all practice visits for all patients.

Because of its mechanistically plausible relationship with BMI, we used the association between ZIP-level food resources and BMI as the primary outcome, with secondary analyses being the associations between other VSURF selected area resources and clinical outcomes.

Robustness checks

In addition to the main analyses, we conducted a series of robustness checks that examined whether different specifications of resources in the area (e.g. resources per capita or resources per capita living in poverty) or different functional forms (e.g. including polynomial terms or using splines) would alter the observed associations between area-level resources and outcomes. We also conducted analyses restricted to those with indicators of lower socioeconomic status (high school diploma or lower educational attainment, living in a ZIP where > 15% of

individuals are in poverty) to ensure the results were applicable to those most likely to utilize the resources studied.

A p-value of < 0.05 was taken to indicate statistical significance. Analyses were conducted in SAS Version 9.4 (Cary, NC), Stata 14 (College Station, TX), and R version 3.3.4 (Vienna, Austria).

Results

Overall, 123,355 participants were included in the study. All participants were eligible for the BMI analyses. Based on inclusion criteria, 43,509 were included in the hypertension analyses, 46,940 were included in the LDL analyses, and 13,127 were included in the diabetes analyses. Demographic characteristics of the overall sample are presented in Table 1. Demographic characteristics of the samples used in the hypertension, LDL cholesterol, and diabetes analyses are presented in eTables 1-3. Overall, the mean age was 52.4 (SD 16.9) years, the sample was 41.5% male, 82.1% non-Hispanic white, 5.8% non-Hispanic black, and 6.5% Hispanic. The median number of years participants were followed in our network was 9 (intraquartile range (IQR): 3, 10), and the median number change of address per year followed was 0.1 (IQR 0.1, 0.25), suggesting that participants resided at their current address for the majority of their time in our network.

In general, individuals living in areas with more resources were had lower educational attainment and higher rates of Medicaid insurance coverage (eTable 4).

Maps depicting the distribution of the resources are presented in Figure 1 and eFigures 2-3.

The mean BMI in the sample was 27.8 (SD 6.2) kg/m^2. In the hypertension analyses, the mean BP was 131.6 (SD 15.8) mmHg. In the LDL analyses, the mean LDL was 102.9 (SD 39.8) mg/dL, and in the diabetes analyses the mean HbA1c was 7.1 (SD 1.5)%.

Among geographic levels assessed, all resources selected were at the ZIP level (Table 2). For the BMI analyses, the selected resources were ZIP level food resources, ZIP level employment resources, and ZIP level nutrition resources. For hypertension analyses, the selected resources were ZIP housing and ZIP nutrition resources. For LDL analyses, the only selected resource was ZIP nutrition resources. For diabetes analyses, the selected resources were ZIP mental health and ZIP substance use resources.

For the BMI analyses, we tested the association between selected resources and BMI, adjusting for the factors described in the statistical analysis section, and accounting for clustering at the clinic and ZIP level with multi-level linear mixed models. We found that resources associated with lower BMI included more food resources (-0.08 kg/m^2 per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m^2, p= .001), employment resources (-0.05 kg/m^2, 95%CI -0.11 to -0.002 kg/m^2, p=.04), and nutrition resources (-0.07 kg/m^2, 95%CI -0.13 to -0.01 kg/m^2,

p=.02) (full models for these and all robustness checks in eAppendix tables 5-16). Table 3 compares mean BMI and obesity prevalence at selected numbers of resources, adjusted for the other factors in the model. For example, the mean BMI in neighborhoods with the median (0) number of food resources was 27.8 kg/m^2, while the mean BMI in neighborhoods in the 75th percentile (3 resources) was 27.5 kg/m^2, and the 90th percentile (8 resources) was 27.1 kg/m^2. Falsification tests found the expected lack of association between afterschool resources and BMI (p=.67).

Robustness checks found that our results did not vary substantially with other specifications of area-level resources (eTables 5-7).

In the hypertension analyses, neither housing resources (-0.05 mm Hg per additional resource, 95%CI -0.16 to 0.06 mm Hg, p=.41) nor nutrition resources (0.01 mm Hg, 95%CI -0.13 to 0.16 mm Hg, p=.87) were associated with systolic blood pressure after adjustment for individual level and area level characteristics. In LDL analyses, nutrition resources (0.10 mg/dL per additional resource, 95%CI -0.36 to 0.55 mg/dL, p=.67) were not associated with LDL cholesterol in adjusted models. In diabetes analyses, neither substance abuse resources (-0.003% per additional resource, 95%CI -0.03 to 0.02%, p=.86) nor mental health resources were associated with HbA1c (-0.003 %, 95%CI -0.03 to 0.02%, p=.76).

In analyses looking at systolic blood pressure among those without a diagnosis of hypertension (i.e., those with no reason for clinical management of blood pressure), food resources were associated with lower systolic blood pressure in linear mixed models adjusted for the same factors as above (-0.08 mm Hg per additional resource, 95%CI -0.15 to -0.01 mm Hg, p=.03). Mean systolic blood pressure was approximately 1 mm Hg lower at the 95th percentile (118.9 mm Hg) of food resources compared with the 50th percentile (119.8 mm Hg).

Full models for all analyses are presented in eTables 8-16.

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/m^2 difference in BMI between individuals in a well-resourced versus poorly resourced ZIP is similar to the 0.6 increase kg/m^2 in BMI in the overall U.S. population from 2006 to 2016.[26]

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.[2,27–29] However, we did not know whether the presence of area resources that might plausibly support health, such as food and nutrition resources, would be associated with lower cardiometabolic risk.

The positive and negative associations between community resources and cardiometabolic risk factors may have important public health implications. The association between increased area resources and lower BMI suggests that efforts to help link patients to community resources, and to help improve the resources landscape within communities, may be a successful strategy for improving population health, particularly for risk factors such as BMI where clinical management may not be prioritized.[13,14,30] This is reinforced by the finding that SBP, among those without hypertension, is lower in those living in areas with more resources. Since SBP does not come under clinical management for those without hypertension, this finding supports the potential for area resources to impact population health, and is consistent with guidelines that recommend lifestyle, rather than pharmacologic, approaches to pre-hypertension treatment.[31] Future work in

this area should investigate whether interventions that link individuals to area resources show clinical benefits.

Our finding should be interpreted in light of several limitations. We did not have access to data regarding use of the resources. This means that we do not know whether individuals made use of the resources in their community. In light of this, the association between ZIP-level resources and outcomes could be viewed analogously to an 'encouragement design' intervention. This means that the association estimated in this study is likely different than the association that would be estimated if analyzing those who were known to use the resource. That association is clearly of policy interest, and should be examined in future work. While we adjusted for several individual-level and area-level socioeconomic status indicators in order to capture the multidimensional nature of socioeconomic status and, thus, reduce confounding, it is possible that residual confounding, owing to unmeasured characteristics, exists, which would tend to reduce the observed associations between area-resources and outcomes. Additional unmeasured covariates that could affect the observed associations include local culture, and the quality of the resources available. Devising methodology to determine the quality of the services provided to help meet health-related social needs is pressing, and will be an important direction for future investigation. Next, our study was cross-sectional, and thus we cannot establish time-ordering between the exposure and the cardiometabolic outcomes. However, we think it is less likely that lower BMI would drive individuals into areas with more resources than vice versa, as areas with

higher resources tended to have other adverse features, such as lower income and higher poverty, which are likely more salient considerations for those choosing where to live. Finally, because of the relatively high residential stability within this primary care population, we only examined the association between current area of residence and the study outcomes. However, for those who do move, this could lead to misclassification, which would tend to bias results to the null. These limitations are balanced by several strengths. We had access to a detailed mapping of area resources, along with detailed individual-level health information. Further, in addition to the multi-level framework we used, the use of falsification tests demonstrated that unadjusted area-level factors are not likely to explain the observed results.

In summary, ZIP-level food, employment, and nutrition resources were associated with BMI differences that were clinically meaningfully and statistically significant. Further, the association between area resources and cardiometabolic risk factors differed based on the specific risk factor. Investing in area resources and linkage programs may be an important way to help reduce cardiometabolic risk for vulnerable individuals, especially for situations not under intensive clinical management.

Acknowledgements

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.

Funding Statement: Research reported in this publication was supported by the National Institute for Diabetes and Digestive and Kidney Disease of the National Institutes of Health, and the National Institute on Minority Health and Health Disparities of the National Institutes of Health under Award Numbers DP2MD010478 (SB), U54MD010724 (SB), and K23DK109200 (SAB). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Author Contribution List: SAB conducted the data analysis, wrote the first draft of the manuscript, and is the guarantor of the article. SAB, EWF, and SJA conceived of the study. GR assisted with data analysis. SB, AV, and GR contributed to interpretation of results and critical revision of the manuscript for intellectual context. All authors (SAB, SB, AV, GR, EF, and SJA) read and approved the final manuscript for submission.

Data Sharing Statement: Statistical code will be available concurrent with publication from the corresponding author. Owing to privacy concerns, study data cannot be made publically available. Study Protocol: Not available.

References

1. Centers for Disease Control and Prevention. Deaths and Mortality. https://www.cdc.gov/nchs/fastats/deaths.htm. Published March 5, 2018. Accessed March 19, 2018.

2. Havranek EP, Mujahid MS, Barr DA, et al. Social Determinants of Risk and Outcomes for Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Circulation*. 2015;132(9):873-898. doi:10.1161/CIR.0000000000000228

3. Berkowitz SA, Baggett TP, Wexler DJ, Huskey KW, Wee CC. Food insecurity and metabolic control among U.S. adults with diabetes. *Diabetes Care*. 2013;36(10):3093-3099. doi:10.2337/dc13-0570

4. Berkowitz SA, Meigs JB, DeWalt D, et al. Material need insecurities, control of diabetes mellitus, and use of health care resources: results of the Measuring Economic Insecurity in Diabetes study. *JAMA Intern Med*. 2015;175(2):257-265. doi:10.1001/jamainternmed.2014.6888

5. Berkowitz SA, Berkowitz TSZ, Meigs JB, Wexler DJ. Trends in food insecurity for adults with cardiometabolic disease in the United States: 2005-2012. *PloS One*. 2017;12(6):e0179172. doi:10.1371/journal.pone.0179172

6. Seligman HK, Laraia BA, Kushel MB. Food insecurity is associated with chronic disease among low-income NHANES participants. *J Nutr*. 2010;140(2):304-310. doi:10.3945/jn.109.112573

7. Baer TE, Scherer EA, Richmond TK, Fleegler EW, Hassan A. Food Insecurity, Weight Status, and Perceived Nutritional and Exercise Barriers in an Urban Youth Population. *Clin Pediatr (Phila)*. 2018;57(2):152-160. doi:10.1177/0009922817693301

8. Morales ME, Berkowitz SA. The Relationship Between Food Insecurity, Dietary Patterns, and Obesity. *Curr Nutr Rep*. 2016;5(1):54-60. doi:10.1007/s13668-016-0153-y

9. Seligman HK, Schillinger D. Hunger and socioeconomic disparities in chronic disease. *N Engl J Med*. 2010;363(1):6-9. doi:10.1056/NEJMp1000072

10. Berkowitz SA, Seligman HK, Choudhry NK. Treat or eat: food insecurity, cost-related medication underuse, and unmet needs. *Am J Med*. 2014;127(4):303-310.e3. doi:10.1016/j.amjmed.2014.01.002

11. Keene DE, Guo M, Murillo S. "That wasn't really a place to worry about diabetes": Housing access and diabetes self-management among low-income adults. *Soc Sci Med 1982*. 2018;197:71-77. doi:10.1016/j.socscimed.2017.11.051

12. Hassan A, Blood EA, Pikcilingis A, et al. Youths' health-related social problems: concerns often overlooked during the medical visit. *J Adolesc Health Off Publ Soc Adolesc Med*. 2013;53(2):265-271. doi:10.1016/j.jadohealth.2013.02.024

13. Hassan A, Scherer EA, Pikcilingis A, et al. Improving Social Determinants of Health: Effectiveness of a Web-Based Intervention. *Am J Prev Med*. 2015;49(6):822-831. doi:10.1016/j.amepre.2015.04.023

14. Berkowitz SA, Hulberg AC, Standish S, Reznor G, Atlas SJ. Addressing Unmet Basic Resource Needs as Part of Chronic Cardiometabolic Disease Management. *JAMA Intern Med*. 2017;177(2):244-252. doi:10.1001/jamainternmed.2016.7691

15. Gottlieb LM, Wing H, Adler NE. A Systematic Review of Interventions on Patients' Social and Economic Needs. *Am J Prev Med*. July 2017. doi:10.1016/j.amepre.2017.05.011

16. Gottlieb LM, Hessler D, Long D, et al. Effects of Social Needs Screening and In-Person Service Navigation on Child Health: A Randomized Clinical Trial. *JAMA Pediatr*. 2016;170(11):e162521. doi:10.1001/jamapediatrics.2016.2521

17. Alley DE, Asomugha CN, Conway PH, Sanghavi DM. Accountable Health Communities--Addressing Social Needs through Medicare and Medicaid. *N Engl J Med*. 2016;374(1):8-11. doi:10.1056/NEJMp1512532

18. Bauer SR, Monuteaux MC, Fleegler EW. Geographic Disparities in Access to Agencies Providing Income-Related Social Services. *J Urban Health Bull N Y Acad Med*. 2015;92(5):853-863. doi:10.1007/s11524-015-9971-2

19. Fleegler E, J. Bottino C, Pikcilingis A, Baker B, Kistler E, Hassan A. Referral System Collaboration Between Public Health and Medical Systems: A Population Health Case Report. *Natl Acad Med Perspect Popul Health Case Rep*. May 2016.

20. Berkowitz SA, Traore CY, Singer DE, Atlas SJ. Evaluating area-based socioeconomic status indicators for monitoring disparities within health care systems: results from a primary care network. *Health Serv Res*. 2015;50(2):398-417. doi:10.1111/1475-6773.12229

21. Atlas SJ, Grant RW, Ferris TG, Chang Y, Barry MJ. Patient-physician connectedness and quality of primary care. *Ann Intern Med*. 2009;150(5):325-335.

22. USDA Food Access Research Atlas Documentation. https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/. Accessed August 11, 2017.

23. Napierala J, Denton N. Measuring Residential Segregation With the ACS: How the Margin of Error Affects the Dissimilarity Index. *Demography*. 2017;54(1):285-309. doi:10.1007/s13524-016-0545-z

24. Genuer R, Poggi J-M, Tuleau-Malot C. Variable Selection Using Random Forests. *Pattern Recogn Lett*. 2010;31(14):2225–2236. doi:10.1016/j.patrec.2010.03.014

25. Genuer R, Poggi J-M, Tuleau-Malot C. VSURF: An R Package for Variable Selection Using Random Forests. *R J*. 2015;7(2):19-33.

26. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *The Lancet*. 2016;387(10026):1377-1396. doi:10.1016/S0140-6736(16)30054-X

27. Thomas AJ, Eberly LE, Davey Smith G, Neaton JD, Stamler J. Race/Ethnicity, Income, Major Risk Factors, and Cardiovascular Disease Mortality. *Am J Public Health*. 2005;95(8):1417-1423. doi:10.2105/AJPH.2004.048165

28. Diez Roux AV. Investigating Neighborhood and Area Effects on Health. *Am J Public Health*. 2001;91(11):1783-1789. doi:10.2105/AJPH.91.11.1783

29. Kelli HM, Hammadah M, Ahmed H, et al. Association Between Living in Food Deserts and Cardiovascular Risk. *Circ Cardiovasc Qual Outcomes*. 2017;10(9):e003532. doi:10.1161/CIRCOUTCOMES.116.003532

30. Garg A, Toy S, Tripodis Y, Silverstein M, Freeman E. Addressing social determinants of health at well child care visits: a cluster RCT. *Pediatrics*. 2015;135(2):e296-304. doi:10.1542/peds.2014-2888

31. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. January 2017:HYP.0000000000000065. doi:10.1161/HYP.0000000000000065

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.

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

BMI Analyses							
Resource*	Minimum	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th 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/m^2, by resource level

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

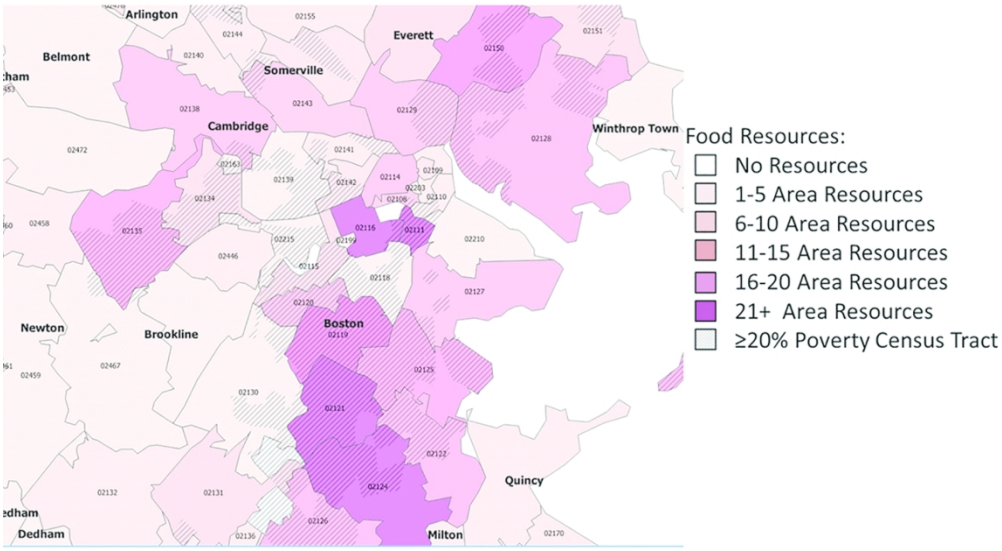


Figure 1

180x101mm (300 x 300 DPI)

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

Technical Appendix

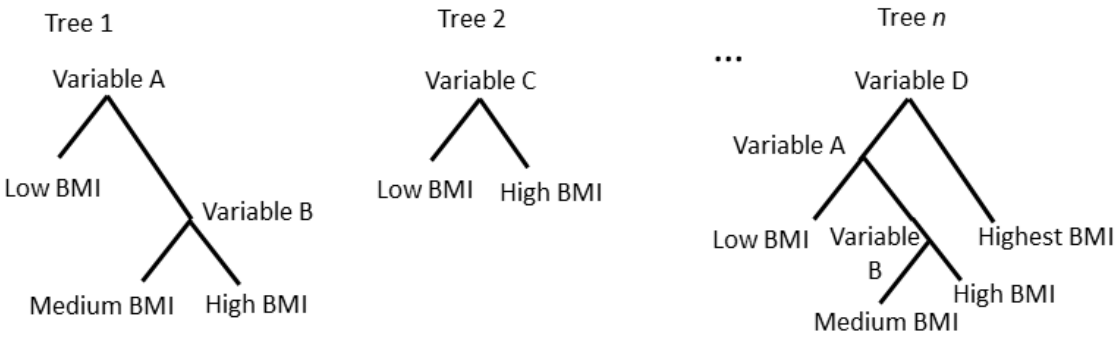
VSURF

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

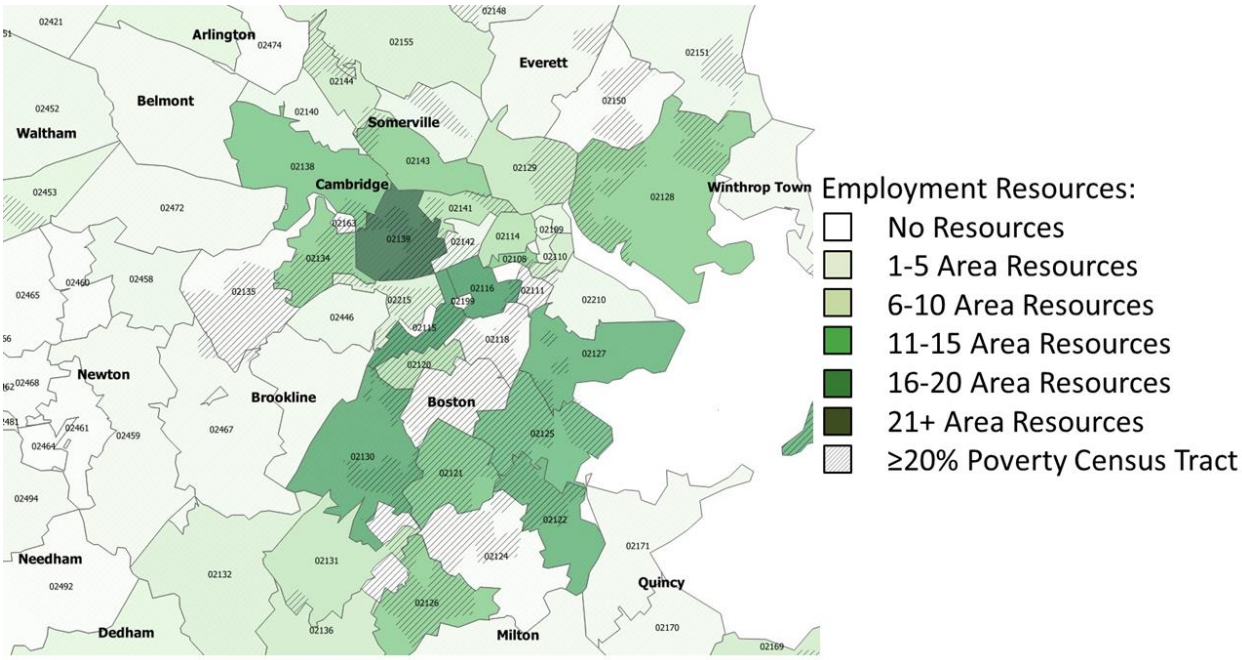
significance testing is not used in the selection of variables, unlike p-value-based selection algorithms.

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

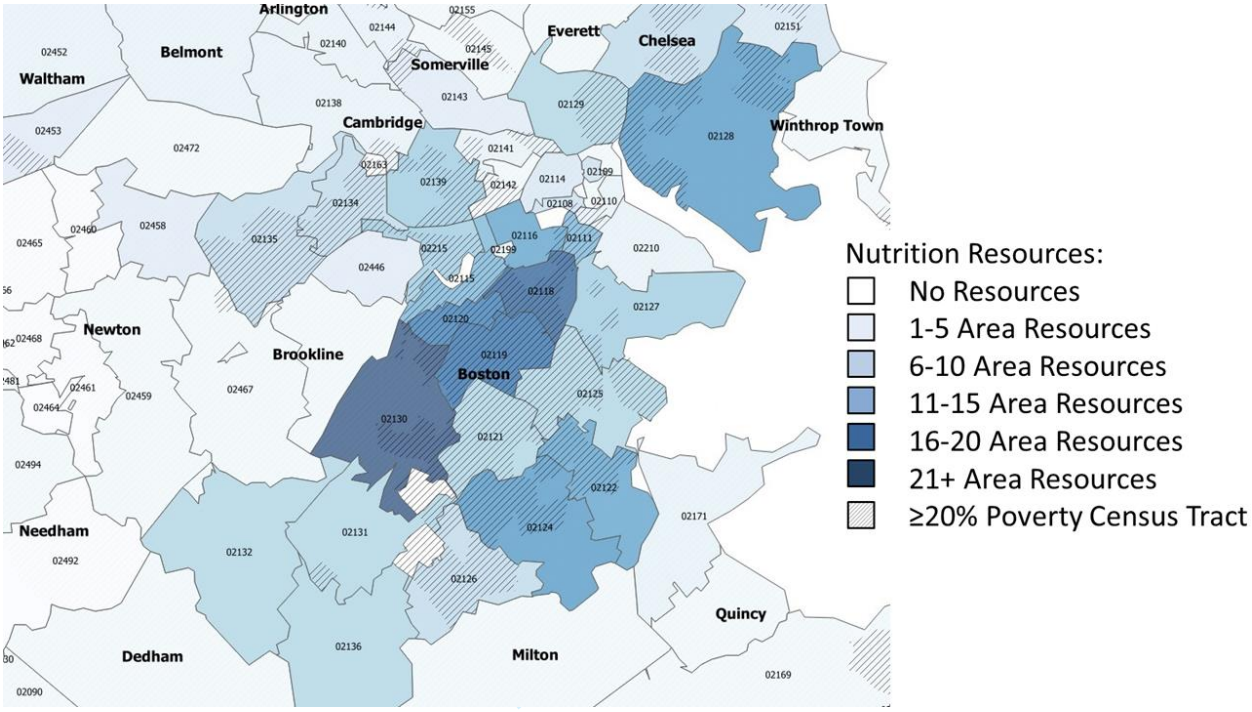


From a random subset of variables and a bootstrap resample of individuals in the derivation cohort, a decision tree that optimally splits the sample is created. This process is repeated in a second bootstrap resample with a second randomly selected subset of variables, and so on until *n* trees (n=2000 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



eFigure 3: Nutrition Resources by ZIP



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)

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)

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)

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

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)

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-025281.R2
Article Type:	Research
Date Submitted by the Author:	07-Jan-2019
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
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	General practice / Family practice, Health services research, Public health
Keywords:	SOCIAL MEDICINE, PRIMARY CARE, Hypertension < CARDIOLOGY, DIABETES & ENDOCRINOLOGY, Cardiac Epidemiology < CARDIOLOGY

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

Seth A. Berkowitz[1-3], Sanjay Basu[4,5], Atheendar Venkataramani[6,7], Gally Reznor[8], Eric W. Fleegler[9,10], Steven J. Atlas[8,9]

[1] Division of General Medicine and Clinical Epidemiology, Department of Medicine, University of North Carolina School of Medicine, Chapel Hill, NC

[2] The Cecil G. Sheps Center for Health Services Research, University of North Carolina at Chapel Hill, Chapel Hill, NC

[3] Center for Health Equity Research, Department of Social Medicine, University of North Carolina School of Medicine, Chapel Hill, NC

[4] Center for Primary Care and Outcomes Research, Center for Population Health Sciences, Departments of Medicine and of Health Research and Policy, Stanford University, Palo Alto, California

[5] Center for Primary Care, Harvard Medical School

[6] Department of Medical Ethics and Health Policy, Perelman School of Medicine, University of Pennsylvania, Philadelphia.

[7] Leonard Davis Institute of Health Economics, University of Pennsylvania, Philadelphia.

[8] Division of General Internal Medicine, Massachusetts General Hospital, Boston, Massachusetts

[9] Harvard Medical School, Boston, Massachusetts

[10] Division of Emergency Medicine, Boston Children's Hospital, Boston, Massachusetts

Corresponding Author and Request for Reprints:

Seth A. Berkowitz, MD MPH

5034 Old Clinic Bldg

CB 7110

Chapel Hill, NC 27599

Tel: 919-966-2276

seth_berkowitz@med.unc.edu

Tables: 3

Figures: 1

Word Count

Abstract: 299/300

Manuscript: 3344/4000

Running Title: Social Service Resources and Cardiometabolic Risk

Key Words: cardiovascular disease, food insecurity, health disparities, socioeconomic status

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

Design: Cross-sectional.

Setting: Data were collected in a primary care network in eastern Massachusetts in 2015.

Participants and Primary and Secondary Outcome Measures: 123,355 participants were included. The primary outcome was body mass index (BMI). The secondary outcomes were systolic blood pressure (SBP), low density lipoprotein cholesterol (LDL), and hemoglobin A1c (HbA1c). All participants were included in BMI analyses. Participants with hypertension were included in SBP analyses. Participants with an indication for cholesterol lowering were included in LDL analyses, and participants with diabetes mellitus were included in HbA1c analyses. We used a random forest-based machine-learning algorithm to identify types of resources associated with study outcomes. We then tested the association of ZIP-level selected resource types (three for BMI, two each for SBP and HbA1c analyses, and one for LDL analyses) with these outcomes, using multi-level models to account for individual-level, clinic-level, and other area-level factors.

Results: Resources associated with lower BMI included more food resources (-0.08 kg/m^2 per additional resource, 95% Confidence Interval[CI] -0.13 to -0.03 kg/m^2),

employment resources (-0.05 kg/m^2, 95%CI -0.11 to -0.002 kg/m^2), and nutrition resources (-0.07 kg/m^2, 95%CI -0.13 to -0.01 kg/m^2). No area resources were associated with differences in SBP, LDL, or HbA1c.

Conclusions: Access to specific local resources is associated with better BMI. Efforts to link patients to area resources, and to improve the resources landscape within communities, may help reduce BMI and improve population health.

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

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

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

particular health-related need may not be straightforward. For example, a food pantry could help alleviate food insecurity, but so could employment.

To help address these issues, and inform further interventions, we sought to study associations between area resources and cardiometabolic risk factors in a large primary care network. Our goal was to understand which resource types were associated with improved levels of BMI, SBP, LDL, and HbA1c, and to determine whether area resources had stronger associations with cardiometabolic risk factors for conditions that are less amenable to clinical management.

Methods

Setting and Study Sample

Data for this study came from two primary sources: an asset mapping of community resources, and electronic health records. The asset mapping came from the HelpSteps database, a comprehensive asset mapping of area resources in eastern Massachusetts.[19] The clinical records came from a primary care network in eastern Massachusetts, a network of 18 primary care practices, including hospital-based, academic, and community health center sites. All adult (age ≥ 18 years) primary care patients seen between January 1, 2012 and December 31, 2015 were included. Data were current on December 31, 2015. The most recent patient address was geocoded for the study. Patients without available addresses were excluded—prior work has shown that only 0.15% of patients in this cohort could not be geocoded.[20]

The Partners Healthcare Human Research Committee approved this analysis, which entailed use of secondary data without patient contact (Protocol Number: 2017P000964).

Patient and Public Involvement

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

Area Resources

HelpSteps (www.helpsteps.com) is a web and mobile screening and referral system for social needs. Originally launched in 2010, the system uses a database of social services throughout the greater Boston area to connect families to appropriate services. The database is maintained in collaboration between Boston Children's Hospital and the Mayor's Health Line at the Boston Public Health Commission. Every agency is contacted at least once per year to maintain the accuracy of the data and to grow the database. HelpSteps contains information on area resources across 16 non-mutually exclusive domains: health, housing, food employment, violence, safety, substance abuse, mental health, education, parenting, nutrition, after school, sexual health, transportation, diabetes, and care transitions. An example of organizations that would be in the food domain are food pantries. The employment

domain would consist of job placement or job training services. And the nutrition domain would include organizations that provide food counseling. Agencies providing multiple resources could be included in more than one domain. Because individual-level data for this study came from 2015, we used information from HelpSteps that was current as of 2015. For this study, 'area resources' are defined as the number of organizations found in the HelpSteps database providing assistance for a given domain and within a given geographic area.

After geocoding the addresses for both individuals and the area resource organization, we created counts, for each individual, of how many resources for each domain were within the same geographic area as they were. We did this at 4 geographic levels in roughly increasing order of size: census tract (using U.S. Census 2010 boundaries), ZIP code tabulation area (which we refer to throughout this paper as 'ZIP' level, owing to common use of the term, again using U.S Census 2010 boundaries), 'neighborhood' (e.g. Allston, Roxbury, a designation based on Boston city planning that may better capture actual movement patterns), and county.

Clinical Outcomes

To assess clinical outcomes, we calculated the mean of all values recorded in 2015 from individual's electronic health record for the following measurements: body mass index (in kg/m^2), systolic blood pressure (in mm Hg), low-density lipoprotein cholesterol (in mg/dL) and HbA1c (%). All values were obtained in the process of usual care.

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 algorithm[21], 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

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

Multi-level modeling

In the test dataset, we fit multi-level linear mixed models to test the association between variables identified in the VSURF step and the outcome of interest. The BMI model included all study participants. The SBP model included those with a diagnosis of hypertension. The LDL model included those with common diagnoses (hypertension, diabetes, coronary heart disease, cerebrovascular disease, congestive heart failure) where LDL lowering is most beneficial. The HbA1c models included those with a diagnosis of diabetes. 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.

Falsification tests

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

Variations in clinical management

To help explore whether variations in the intensity of clinical management could explain whether community resources were associated with health outcomes, we also used the above modeling approach to test whether area resources were

associated with SBP in those *without* a diagnosis of hypertension. The primary care network in the study has quality improvement program that emphasize the importance of SBP, LDL, and HbA1c control in appropriate clinical populations. Since BMI (in any population) and SBP control in those without a diagnosis of hypertension are not included in these programs, we reasoned that area resources may be more important when clinicians are not intensively attempting to impact an outcome. We focused on BMI and systolic blood pressure among those *without* hypertension for this because BMI and SBP are routinely measured at all practice visits for all patients.

Because of its mechanistically plausible relationship with BMI, we used the association between ZIP-level food resources and BMI as the primary outcome, with secondary analyses being the associations between other VSURF selected area resources and clinical outcomes.

Robustness checks

In addition to the main analyses, we conducted a series of robustness checks that examined whether different specifications of resources in the area (e.g. resources per capita or resources per capita living in poverty) or different functional forms (e.g. including polynomial terms or using splines) would alter the observed associations between area-level resources and outcomes. We also conducted analyses restricted to those with indicators of lower socioeconomic status (high

school diploma or lower educational attainment, living in a ZIP where > 15% of individuals are in poverty) to ensure the results were applicable to those most likely to utilize the resources studied.

A p-value of < 0.05 was taken to indicate statistical significance. Analyses were conducted in SAS Version 9.4 (Cary, NC), Stata 14 (College Station, TX), and R version 3.3.4 (Vienna, Austria).

Results

Overall, 123,355 participants were included in the study. All participants were eligible for the BMI analyses. Based on inclusion criteria, 43,509 were included in the hypertension analyses, 46,940 were included in the LDL analyses, and 13,127 were included in the diabetes analyses. Demographic characteristics of the overall sample are presented in Table 1. Demographic characteristics of the samples used in the hypertension, LDL cholesterol, and diabetes analyses are presented in eTables 1-3. Overall, the mean age was 52.4 (SD 16.9) years, the sample was 41.5% male, 82.1% non-Hispanic white, 5.8% non-Hispanic black, and 6.5% Hispanic. The median number of years participants were followed in our network was 9 (intraquartile range (IQR): 3, 10), and the median number change of address per year followed was 0.1 (IQR 0.1, 0.25), suggesting that participants resided at their current address for the majority of their time in our network.

In general, individuals living in areas with more resources were had lower educational attainment and higher rates of Medicaid insurance coverage (eTable 4). Maps depicting the distribution of the resources are presented in Figure 1 and eFigures 2-3.

The mean BMI in the sample was 27.8 (SD 6.2) kg/m^2. In the hypertension analyses, the mean BP was 131.6 (SD 15.8) mmHg. In the LDL analyses, the mean LDL was 102.9 (SD 39.8) mg/dL, and in the diabetes analyses the mean HbA1c was 7.1 (SD 1.5)%.

Among geographic levels assessed, all resources selected were at the ZIP level (Table 2). For the BMI analyses, the selected resources were ZIP level food resources, ZIP level employment resources, and ZIP level nutrition resources. For hypertension analyses, the selected resources were ZIP housing and ZIP nutrition resources. For LDL analyses, the only selected resource was ZIP nutrition resources. For diabetes analyses, the selected resources were ZIP mental health and ZIP substance use resources.

For the BMI analyses, we tested the association between selected resources and BMI, adjusting for the factors described in the statistical analysis section, and accounting for clustering at the clinic and ZIP level with multi-level linear mixed models. We found that resources associated with lower BMI included more food resources (-0.08 kg/m^2 per additional resource, 95% Confidence Interval[CI] -0.13

to -0.03 kg/m^2, p= .001), employment resources (-0.05 kg/m^2, 95%CI -0.11 to -0.002 kg/m^2, p=.04), and nutrition resources (-0.07 kg/m^2, 95%CI -0.13 to -0.01 kg/m^2, p=.02) (full models for these and all robustness checks in eAppendix tables 5-16). Table 3 compares mean BMI and obesity prevalence at selected numbers of resources, adjusted for the other factors in the model. For example, the mean BMI in neighborhoods with the median (0) number of food resources was 27.8 kg/m^2, while the mean BMI in neighborhoods in the 75th percentile (3 resources) was 27.5 kg/m^2, and the 90th percentile (8 resources) was 27.1 kg/m^2. Falsification tests found the expected lack of association between afterschool resources and BMI (p=.67).

Robustness checks found that our results did not vary substantially with other specifications of area-level resources (eTables 5-7).

In the hypertension analyses, neither housing resources (-0.05 mm Hg per additional resource, 95%CI -0.16 to 0.06 mm Hg, p=.41) nor nutrition resources (0.01 mm Hg, 95%CI -0.13 to 0.16 mm Hg, p=.87) were associated with systolic blood pressure after adjustment for individual level and area level characteristics. In LDL analyses, nutrition resources (0.10 mg/dL per additional resource, 95%CI -0.36 to 0.55 mg/dL, p=.67) were not associated with LDL cholesterol in adjusted models. In diabetes analyses, neither substance abuse resources (-0.003% per additional resource, 95%CI -0.03 to 0.02%, p=.86) nor mental health resources were associated with HbA1c (-0.003 %, 95%CI -0.03 to 0.02%, p=.76).

In analyses looking at systolic blood pressure among those without a diagnosis of hypertension (i.e., those with no reason for clinical management of blood pressure), food resources were associated with lower systolic blood pressure in linear mixed models adjusted for the same factors as above (-0.08 mm Hg per additional resource, 95%CI -0.15 to -0.01 mm Hg, p=.03). Mean systolic blood pressure was approximately 1 mm Hg lower at the 95th percentile (118.9 mm Hg) of food resources compared with the 50th percentile (119.8 mm Hg).

Full models for all analyses are presented in eTables 8-16.

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/m^2 difference in BMI between individuals in a well-resourced versus poorly resourced ZIP is similar to the 0.6 increase kg/m^2 in BMI in the overall U.S. population from 2006 to 2016.[26]

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.[2,27–29] However, we did not know whether the presence of area resources that might plausibly support health, such as food and nutrition resources, would be associated with lower cardiometabolic risk.

The positive and negative associations between community resources and cardiometabolic risk factors may have important public health implications. The association between increased area resources and lower BMI suggests that efforts to help link patients to community resources, and to help improve the resources landscape within communities, may be a successful strategy for improving population health, particularly for risk factors such as BMI where clinical management may not be prioritized.[13,14,30] This is reinforced by the finding that SBP, among those without hypertension, is lower in those living in areas with more resources. Since SBP does not come under clinical management for those without hypertension, this finding supports the potential for area resources to impact population health, and is consistent with guidelines that recommend lifestyle, rather

than pharmacologic, approaches to pre-hypertension treatment.[31] Future work in this area should investigate whether interventions that link individuals to area resources show clinical benefits.

Our finding should be interpreted in light of several limitations. We did not have access to data regarding use of the resources. This means that we do not know whether individuals made use of the resources in their community. In light of this, the association between ZIP-level resources and outcomes could be viewed analogously to an 'encouragement design' intervention. This means that the association estimated in this study is likely different than the association that would be estimated if analyzing those who were known to use the resource. That association is clearly of policy interest, and should be examined in future work. While we adjusted for several individual-level and area-level socioeconomic status indicators in order to capture the multidimensional nature of socioeconomic status and, thus, reduce confounding, it is possible that residual confounding, owing to unmeasured characteristics, exists, which would tend to reduce the observed associations between area-resources and outcomes. Additional unmeasured covariates that could affect the observed associations include local culture, and the quality of the resources available. Devising methodology to determine the quality of the services provided to help meet health-related social needs is pressing, and will be an important direction for future investigation. Next, our study was cross-sectional, and thus we cannot establish time-ordering between the exposure and the cardiometabolic outcomes. However, we think it is less likely that lower BMI would

drive individuals into areas with more resources than vice versa, as areas with higher resources tended to have other adverse features, such as lower income and higher poverty, which are likely more salient considerations for those choosing where to live. Finally, because of the relatively high residential stability within this primary care population, we only examined the association between current area of residence and the study outcomes. However, for those who do move, this could lead to misclassification, which would tend to bias results to the null. These limitations are balanced by several strengths. We had access to a detailed mapping of area resources, along with detailed individual-level health information. Further, in addition to the multi-level framework we used, the use of falsification tests demonstrated that unadjusted area-level factors are not likely to explain the observed results.

In summary, ZIP-level food, employment, and nutrition resources were associated with BMI differences that were clinically meaningfully and statistically significant. Further, the association between area resources and cardiometabolic risk factors differed based on the specific risk factor. Investing in area resources and linkage programs may be an important way to help reduce cardiometabolic risk for vulnerable individuals, especially for situations not under intensive clinical management.

Acknowledgements

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.

Funding Statement: Research reported in this publication was supported by the National Institute for Diabetes and Digestive and Kidney Disease of the National Institutes of Health, and the National Institute on Minority Health and Health Disparities of the National Institutes of Health under Award Numbers DP2MD010478 (SB), U54MD010724 (SB), and K23DK109200 (SAB). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Author Contribution List: SAB conducted the data analysis, wrote the first draft of the manuscript, and is the guarantor of the article. SAB, EWF, and SJA conceived of the study. GR assisted with data analysis. SB, AV, and GR contributed to interpretation of results and critical revision of the manuscript for intellectual context. All authors (SAB, SB, AV, GR, EWF, and SJA) read and approved the final manuscript for submission.

Data Sharing Statement: Statistical code will be available concurrent with publication from the corresponding author. Owing to privacy concerns, study data cannot be made publically available. Study Protocol: Not available.

References

1. Centers for Disease Control and Prevention. Deaths and Mortality. https://www.cdc.gov/nchs/fastats/deaths.htm. Published March 5, 2018. Accessed March 19, 2018.

2. Havranek EP, Mujahid MS, Barr DA, et al. Social Determinants of Risk and Outcomes for Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Circulation*. 2015;132(9):873-898. doi:10.1161/CIR.0000000000000228

3. Berkowitz SA, Baggett TP, Wexler DJ, Huskey KW, Wee CC. Food insecurity and metabolic control among U.S. adults with diabetes. *Diabetes Care*. 2013;36(10):3093-3099. doi:10.2337/dc13-0570

4. Berkowitz SA, Meigs JB, DeWalt D, et al. Material need insecurities, control of diabetes mellitus, and use of health care resources: results of the Measuring Economic Insecurity in Diabetes study. *JAMA Intern Med*. 2015;175(2):257-265. doi:10.1001/jamainternmed.2014.6888

5. Berkowitz SA, Berkowitz TSZ, Meigs JB, Wexler DJ. Trends in food insecurity for adults with cardiometabolic disease in the United States: 2005-2012. *PloS One*. 2017;12(6):e0179172. doi:10.1371/journal.pone.0179172

6. Seligman HK, Laraia BA, Kushel MB. Food insecurity is associated with chronic disease among low-income NHANES participants. *J Nutr*. 2010;140(2):304-310. doi:10.3945/jn.109.112573

7. Baer TE, Scherer EA, Richmond TK, Fleegler EW, Hassan A. Food Insecurity, Weight Status, and Perceived Nutritional and Exercise Barriers in an Urban Youth Population. *Clin Pediatr (Phila)*. 2018;57(2):152-160. doi:10.1177/0009922817693301

8. Morales ME, Berkowitz SA. The Relationship Between Food Insecurity, Dietary Patterns, and Obesity. *Curr Nutr Rep*. 2016;5(1):54-60. doi:10.1007/s13668-016-0153-y

9. Seligman HK, Schillinger D. Hunger and socioeconomic disparities in chronic disease. *N Engl J Med*. 2010;363(1):6-9. doi:10.1056/NEJMp1000072

10. Berkowitz SA, Seligman HK, Choudhry NK. Treat or eat: food insecurity, cost-related medication underuse, and unmet needs. *Am J Med*. 2014;127(4):303-310.e3. doi:10.1016/j.amjmed.2014.01.002

11. Keene DE, Guo M, Murillo S. "That wasn't really a place to worry about diabetes": Housing access and diabetes self-management among low-income adults. *Soc Sci Med 1982*. 2018;197:71-77. doi:10.1016/j.socscimed.2017.11.051

12. Hassan A, Blood EA, Pikcilingis A, et al. Youths' health-related social problems: concerns often overlooked during the medical visit. *J Adolesc Health Off Publ Soc Adolesc Med*. 2013;53(2):265-271. doi:10.1016/j.jadohealth.2013.02.024

13. Hassan A, Scherer EA, Pikcilingis A, et al. Improving Social Determinants of Health: Effectiveness of a Web-Based Intervention. *Am J Prev Med*. 2015;49(6):822-831. doi:10.1016/j.amepre.2015.04.023

14. Berkowitz SA, Hulberg AC, Standish S, Reznor G, Atlas SJ. Addressing Unmet Basic Resource Needs as Part of Chronic Cardiometabolic Disease Management. *JAMA Intern Med*. 2017;177(2):244-252. doi:10.1001/jamainternmed.2016.7691

15. Gottlieb LM, Wing H, Adler NE. A Systematic Review of Interventions on Patients' Social and Economic Needs. *Am J Prev Med*. July 2017. doi:10.1016/j.amepre.2017.05.011

16. Gottlieb LM, Hessler D, Long D, et al. Effects of Social Needs Screening and In-Person Service Navigation on Child Health: A Randomized Clinical Trial. *JAMA Pediatr*. 2016;170(11):e162521. doi:10.1001/jamapediatrics.2016.2521

17. Alley DE, Asomugha CN, Conway PH, Sanghavi DM. Accountable Health Communities--Addressing Social Needs through Medicare and Medicaid. *N Engl J Med*. 2016;374(1):8-11. doi:10.1056/NEJMp1512532

18. Bauer SR, Monuteaux MC, Fleegler EW. Geographic Disparities in Access to Agencies Providing Income-Related Social Services. *J Urban Health Bull N Y Acad Med*. 2015;92(5):853-863. doi:10.1007/s11524-015-9971-2

19. Fleegler E, J. Bottino C, Pikcilingis A, Baker B, Kistler E, Hassan A. Referral System Collaboration Between Public Health and Medical Systems: A Population Health Case Report. *Natl Acad Med Perspect Popul Health Case Rep*. May 2016.

20. Berkowitz SA, Traore CY, Singer DE, Atlas SJ. Evaluating area-based socioeconomic status indicators for monitoring disparities within health care systems: results from a primary care network. *Health Serv Res*. 2015;50(2):398-417. doi:10.1111/1475-6773.12229

21. Atlas SJ, Grant RW, Ferris TG, Chang Y, Barry MJ. Patient-physician connectedness and quality of primary care. *Ann Intern Med*. 2009;150(5):325-335.

22. USDA Food Access Research Atlas Documentation. https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/. Accessed August 11, 2017.

23. Napierala J, Denton N. Measuring Residential Segregation With the ACS: How the Margin of Error Affects the Dissimilarity Index. *Demography*. 2017;54(1):285-309. doi:10.1007/s13524-016-0545-z

24. Genuer R, Poggi J-M, Tuleau-Malot C. Variable Selection Using Random Forests. *Pattern Recogn Lett*. 2010;31(14):2225–2236. doi:10.1016/j.patrec.2010.03.014

25. Genuer R, Poggi J-M, Tuleau-Malot C. VSURF: An R Package for Variable Selection Using Random Forests. *R J*. 2015;7(2):19-33.

26. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *The Lancet*. 2016;387(10026):1377-1396. doi:10.1016/S0140-6736(16)30054-X

27. Thomas AJ, Eberly LE, Davey Smith G, Neaton JD, Stamler J. Race/Ethnicity, Income, Major Risk Factors, and Cardiovascular Disease Mortality. *Am J Public Health*. 2005;95(8):1417-1423. doi:10.2105/AJPH.2004.048165

28. Diez Roux AV. Investigating Neighborhood and Area Effects on Health. *Am J Public Health*. 2001;91(11):1783-1789. doi:10.2105/AJPH.91.11.1783

29. Kelli HM, Hammadah M, Ahmed H, et al. Association Between Living in Food Deserts and Cardiovascular Risk. *Circ Cardiovasc Qual Outcomes*. 2017;10(9):e003532. doi:10.1161/CIRCOUTCOMES.116.003532

30. Garg A, Toy S, Tripodis Y, Silverstein M, Freeman E. Addressing social determinants of health at well child care visits: a cluster RCT. *Pediatrics*. 2015;135(2):e296-304. doi:10.1542/peds.2014-2888

31. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. January 2017:HYP.0000000000000065. doi:10.1161/HYP.0000000000000065

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.

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

BMI Analyses							
Resource*	Minimum	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th 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/m^2, by resource level

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

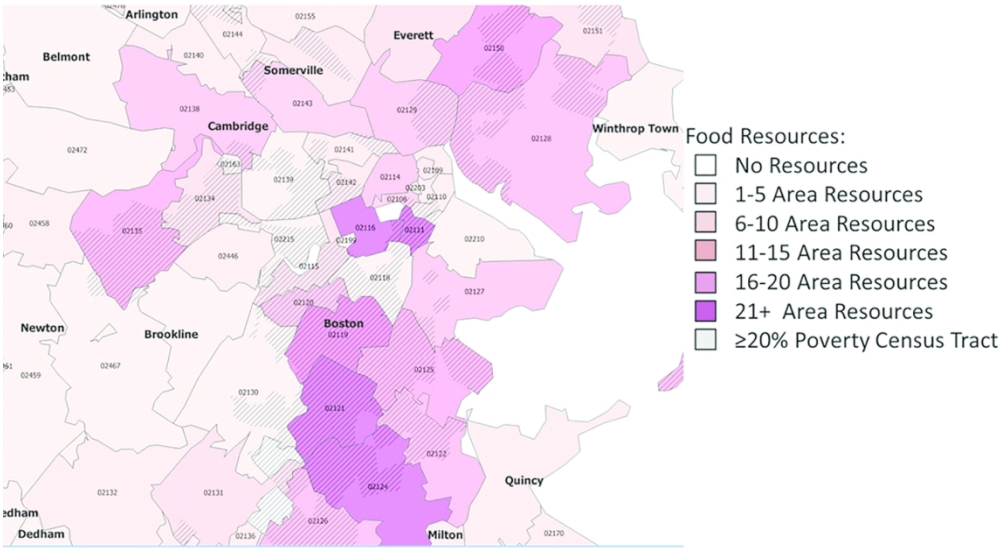


Figure 1

180x101mm (300 x 300 DPI)

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

Technical Appendix

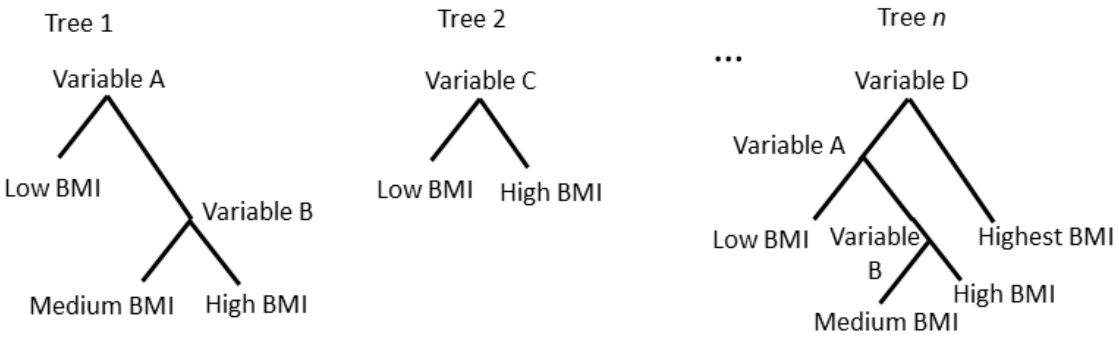
VSURF

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

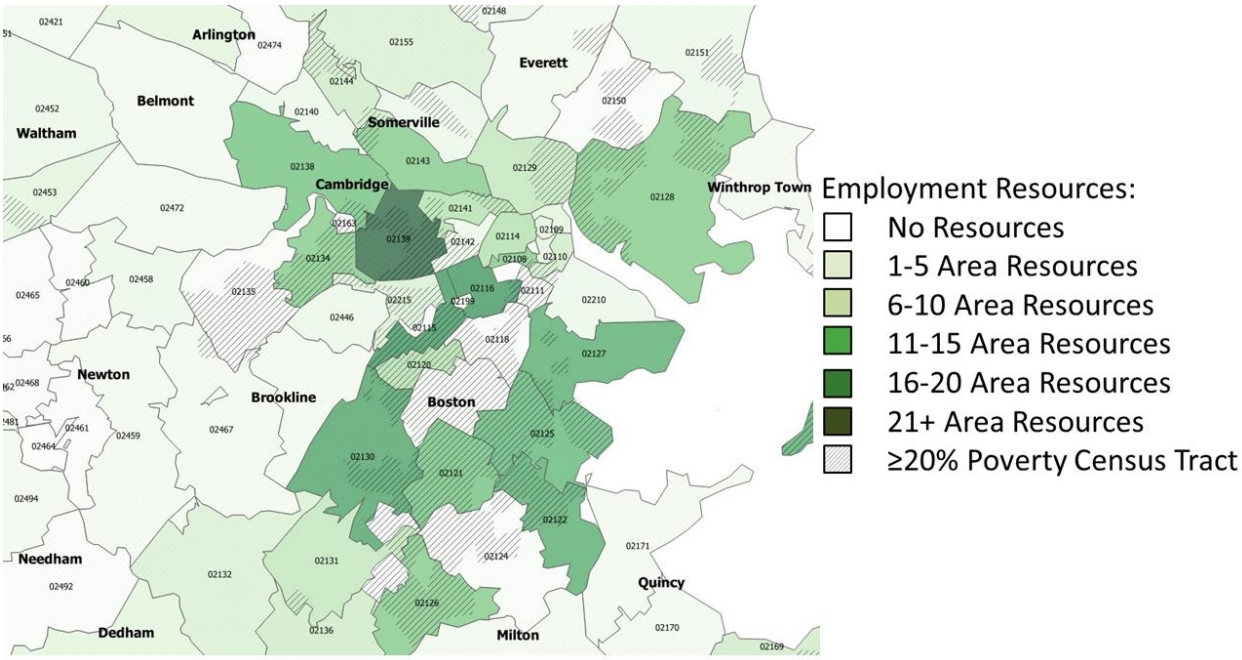
significance testing is not used in the selection of variables, unlike p-value-based selection algorithms.

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

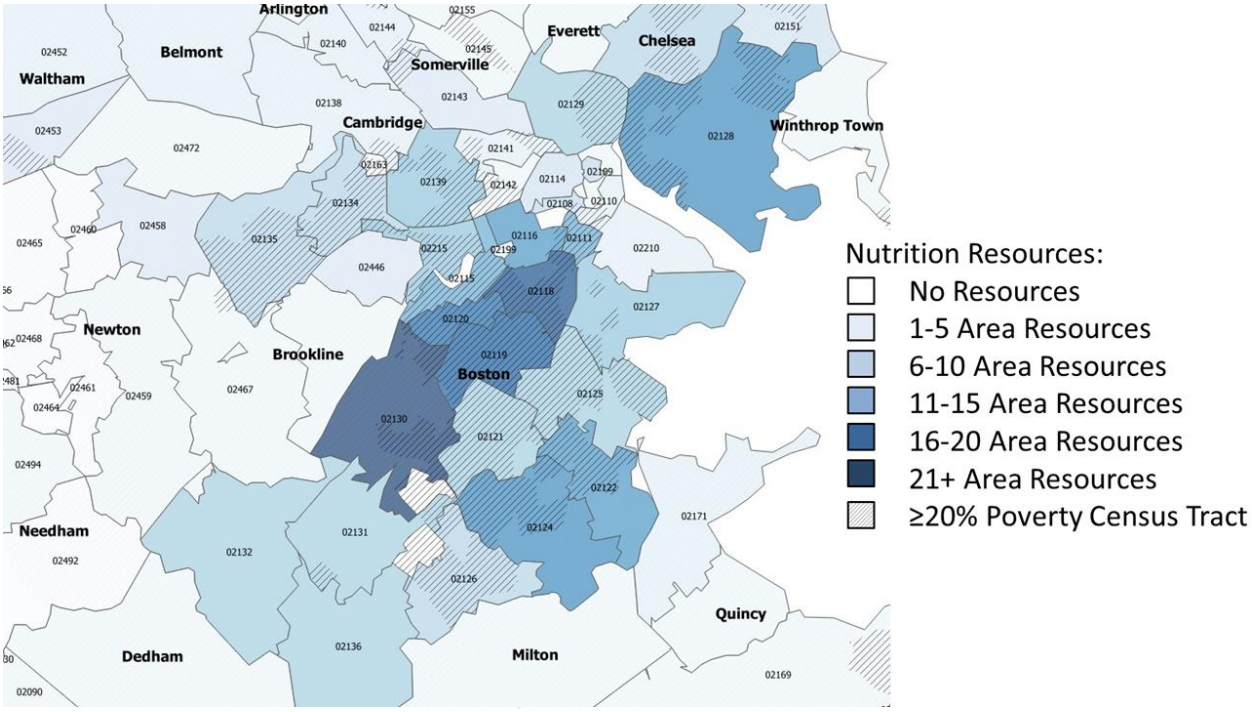


From a random subset of variables and a bootstrap resample of individuals in the derivation cohort, a decision tree that optimally splits the sample is created. This process is repeated in a second bootstrap resample with a second randomly selected subset of variables, and so on until *n* trees (n=2000 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



eFigure 3: Nutrition Resources by ZIP



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)

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)

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)

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

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)

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.