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Geographic disparities in Healthy Eating Index scores (HEI-2005 and 2010) by residential property values: Findings from Seattle Obesity Study (SOS)

Adam Drewnowski, PhD¹, Anju Aggarwal, PhD¹, Andrea Cook, PhD², Orion Stewart, MUP³, and Anne Vernez Moudon, DrSc^{3,4}

¹Center for Public Health Nutrition, School of Public Health, University of Washington, Seattle, WA

²Biostatistics Unit, Group Health Research Institute, Seattle, WA and Department of Biostatistics, School of Public Health, University of Washington, Seattle, WA

³Department of Urban Design and Planning, College of Built Environments, University of Washington, Seattle, WA

⁴Urban Form Lab, University of Washington, Seattle, WA

Abstract

Background—Higher socioeconomic status (SES) has been linked with higher-quality diets. New GIS methods allow for geographic mapping of diet quality at a very granular level.

Objective—To examine the geographic distribution of two measures of diet quality: Healthy Eating Index (HEI 2005 and HEI 2010) in relation to residential property values in Seattle-King County.

Methods—The Seattle Obesity Study (SOS) collected data from a population-based sample of King County adults in 2008–09. Socio-demographic data were obtained by 20-min telephone survey. Dietary data were obtained from food frequency questionnaires (FFQs). Home addresses were geocoded to the tax parcel and residential property values were obtained from the King County tax assessor. Multivariable regression analyses using 1,116 adults tested associations between SES variables and diet quality measured (HEI scores).

Results—Residential property values, education, and incomes were associated with higher HEI scores in bivariate analyses. Property values were not collinear with either education or income. In adjusted multivariable models, education and residential property were better associated with HEI,

Corresponding author: Adam Drewnowski, Box 353410, University of Washington, Seattle, WA 98195, adamdrew@uw.edu Phone: 206-543-8016. Fax: 206-685-1696.

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compared to than income. Mapping of HEI-2005 and HEI-2010 at the census block level illustrated the geographic distribution of diet quality across Seattle-King County.

Conclusion—The use of residential property values, an objective measure of SES, allowed for the first visual exploration of diet quality at high spatial resolution: the census block level.

Keywords

healthy eating index; residential property values; diet quality; geographic information systems; socio-economic status

INTRODUCTION

Differences in diet quality may contribute to observed disparities in weights and health across socioeconomic groups (Drewnowski and Darmon 2005; Drewnowski and Specter 2004). In general, higher socioeconomic status (SES) is associated with higher-quality diets (Acar Tek, et al. 2011; Darmon and Drewnowski 2008; Ervin 2011; Galea, et al. 2011; Galobardes, et al. 2001; Groth, et al. 2001; Hulshof, et al. 2003; Kant and Graubard 2007; Keller, et al. 1997; Lallukka, et al. 2007; Marmot 2005; Ricciuto and Tarasuk 2007; Wang and Zhang 2006). Disparities in diets and health have also been linked to neighborhood food environments (Hackett, et al. 2008; Penney, et al. 2014; Rahmanian, et al. 2014; Raja, et al. 2008). There are limited data on the spatial distribution of dietary behaviors (Lucan and Mitra 2011), or on the potential gaps in diet quality between residents of the wealthiest and the poorest areas.

In most US-based studies, measures of SES were restricted to two variables: education and incomes (Braveman, et al. 2005; Ogden, et al. 2010). The often-missing income variable is dependent on employment, retirement, or other life events. Hence, education was often used as the only SES measure (Kushi, et al. 1988; Zhang and Wang 2004). When both income and education were missing, smoking, physical activity, alcohol consumption, and food patterns served as proxy variables to adjust for SES (Rimm, et al. 1993; Stampfer, et al. 1993). However, none of these variables have been geo-localized to provide additional insights into the socioeconomic determinants of health.

Property values, an alternate measure of SES, can be geo-localized. Residential property values at tax parcel level provide an objective measure of SES that is tied to a specific geographic location (Moudon, et al. 2011). Publicly available residential property values may capture such components of SES as economic security, accumulated assets and net worth (Braveman, et al. 2005; Krieger, et al. 1997; Pollack, et al. 2007). Linked in past research to area-based deprivation indices (Krieger, et al. 2005; Moudon, et al. 2011), property values represent another wealth measure for health studies (Drewnowski, et al. 2014; Drewnowski, et al. 2015; Moudon, et al. 2011; Rehm, et al. 2012). At this time, the relation between residential property values and diet quality has not been fully explored.

This study explored the relation between two measures of diet quality: the Healthy Eating Index 2005 and 2010 and residential property values at the tax parcel level, the finest geographic resolution available. The HEI 2005 and HEI 2010 are formal measures of diet

quality, developed by the US Department of Agriculture to track compliance with the Dietary Guidelines for Americans (Rehm et al. 2015). Their use represents an advance over past studies, many of which used selected nutrient intakes or the consumption of produce or fast foods as proxy measures of diet quality. Maps of the geographic distribution of HEI scores at the census block level were used to illustrate the relation between diet quality and the geo-localized SES variable. A visual display of HEI scores by geographic area would provide new insights into the spatial aspects of nutritional epidemiology.

METHODS

Participants and procedures

The Seattle Obesity Study (SOS) was based on a stratified random sample of 2,001 men and women living in King County, WA (Aggarwal, et al. 2011; Drewnowski, et al. 2012; Moudon, et al. 2011). King County contains the city of Seattle and much of the surrounding metropolitan area, and thus contains a range of urban and suburban environments. Randomly generated telephone numbers were matched to residential addresses from commercial vendors and a pre-notification letter was sent out to targeted households. An adult household member was randomly selected to be the respondent. A 20-minute telephone survey, modeled on the Behavioral Risk Factors Surveillance System (BRFSS), was used to obtain socio-demographic and health data.

Survey participants were asked to complete a G-SEL version of the Food Frequency Questionnaire (FFQ) developed by the Fred Hutchinson Cancer Research Center (FHCRC) to report their usual dietary intakes over the past year (Neuhouser, et al. 1999; Patterson, et al. 1999). Those who agreed to participate (n=1,905 or 95%) were sent the FFQ to be returned in a stamped addressed envelope. Completed FFQs were returned by 1,318 respondents, a 69% response rate. No significant differences were observed between FFQ responders and non-responders by key sociodemographic (such as age, gender, race, income and education), and health indicators (such as perceived health status and obesity). Participants reported the frequency of consumption of ~150 foods and beverages along with portion size. Completed FFQs were checked for data quality and completeness and were sent to FHCRC for dietary analyses (Aggarwal, et al. 2011; Monsivais and Drewnowski 2009). Nutrient composition analyses of dietary intake data yielded dietary energy (kcal), macro- and micronutrient intakes, and the HEI-2005 score for each respondent.

Diet quality measure: Health Eating Index

HEI-2005—The Healthy Eating Index (HEI-2005) is a measure of diet quality (Guenther, et al. 2005) developed by the US Department of Agriculture. It measures compliance with 2005 dietary recommendations and guidelines. The HEI 2005 consists of 12 components – 9 adequacy components: total fruit (5 points), whole fruit (5 points), total vegetables (5 points), dark green and orange vegetables and legumes (5 points), total grains (5 points), whole grains (5 points), milk (10 points), meats and beans (10 points), oils (10 points). The 3 moderation components (higher scores indicating lower consumption) include sodium (10 points), saturated fat (10 points), and calories from solid fats, alcohol and added sugars (SoFAAS) (20 points)). The HEI scores can range from 0 to 100. The higher the score, the

better is the diet quality. HEI scores can also be used to categorize diets into - good (HEI score ≥ 80), fair (HEI 50 – <80), and bad (HEI <50). For present analyses, HEI-2005 score was treated as a continuous outcome variable with a maximum score of 100.

HEI-2010—The HEI 2010 was developed to assess compliance with the 2010 Dietary Guidelines for Americans (Guenther, et al. 2013). It has all the 12 components of HEI-2005, with certain exceptions. The nine adequacy components (with higher scores reflecting higher consumption) include total vegetables (5 points), greens and beans (5 points), total fruit (5 points), whole fruit (5 points), whole grains (10 points), dairy (10 points), total protein foods (5 points), seafood and plant proteins (5 points) and ratio of polyunsaturated and monounsaturated fatty acids to saturated fatty acids (10 points). Three moderation components (higher scores indicating lower consumption) include refined grains (10 points), sodium (10 points) and energy from solid fat, alcohol and added sugars (SoFAAS) (20 points). Energy from SoFAAS is a summary measure of “empty calories” or discretionary calories. Similar to HEI-2005, the maximum HEI-2010 score is also 100 points, and can be used to categorize diets into good, fair or needs improvement. For present analyses, it was treated as the continuous variable, where higher score indicates better diets.

Demographic variables and socioeconomic indicators

The demographic variables of interest – age, gender, race/ethnicity, household size, employment (retired or not) and home ownership – were obtained through the telephone survey. Annual household incomes were grouped into 3 categories: lower income ($< \$50,000/\text{year}$), middle income ($50,000 - <100,000/\text{year}$) and higher income ($\geq 100,000/\text{year}$). Educational attainment was collapsed into 3 categories: $<12\text{y}$ (“high school or less”), $12-16\text{y}$ (“some college”), and $\geq 16\text{y}$ (“college graduates or higher”).

Residential property values for the 2008 tax year at the parcel level were obtained from the King County tax assessor. These data capture market value of properties with the assessment value per dwelling unit calculated as the combined value of both land and improvements attached to the land (such as driveways, buildings). The assessed value per unit was calculated as the sum of a parcel’s land and improvement values. For parcels with multiple residential units (e.g., condominiums), the assessed value was divided by the number of residential units on that parcel. The detailed methodology to develop this metric has been published previously (Moudon, et al. 2011). For analytical purposes, residential property values per dwelling were converted into tertiles. The data were collected from November 2008 to April 2009 and analyzed in 2013-2014. All study protocols were approved by the University of Washington Institutional Review Board.

Statistical analyses

The present analyses were restricted to SOS participants who returned the FFQ, without extreme energy intakes reported ($<500\text{kcal/d}$ or $>5000\text{kcal/d}$) (N removed = 23), not missing data on geocoded location (N removed = 17), demographics (N removed = 20) and self-reported income (N removed = 142). No significant socio-demographic differences were observed among respondents with missing data on FFQ or addresses vs. those who provided complete data. The final analytical sample consisted of 1,116 respondents.

We calculated unadjusted means and standard deviations for HEI by key demographics and SES variables. To assess the relationship between residential property value and participants' socio-demographic characteristics, we calculated unadjusted proportions of a given characteristic within a tertile of property value (low, medium, and high) (e.g. proportion male with low property value). Pearson's Chi-Square test was used to assess the statistical significance.

To evaluate the associations of three SES measures with each HEI-2005 and HEI-2010 score, we ran a series of analyses at the individual level. First, we fit three linear regression models assessing the bivariate relation of education, annual household income, and residential property value with both HEI scores after adjusting for age, gender, race, and home ownership status (**Model 1**). Second, we re-ran another linear regression model to evaluate if income and education were independently associated with HEI-2005 and 2010 scores (**Model 2**). In this model, both income and education were added in the model together along with other covariates from Model 1. Last, we fit third regression model evaluating whether residential property value, rather than income, was equally associated with HEI scores (**Model 3**). This model was adjusted for education and covariates from Model 1. To compare goodness of fit tests across models, Akaike's information criteria (AIC) and adjusted R^2 values were computed. Lower the AIC value and higher the adjusted R^2 value, better is the model fit. The fitted models are shown in Appendix 1.

We further mapped the results of the regression models in space by predicting the census block HEI values in Seattle and King County, based on the observed associations between HEI values and residential property values from SOS data. For this, we first computed mean HEI scores for each decile of residential property values for SOS I participants. Then residential property values at the tax parcel level for all households in Seattle-King County were aggregated by census block and were split into deciles for Seattle and King County. Each census block was assigned a mean HEI score for that decile of property value from SOS. In the health field, similar techniques have been applied to identify health inequities across Britain (Ballas, et al. 2006) and obesogenic environments for children across Leeds, UK (Edwards and Clarke 2009). Our previous studies have shown that multiple characteristics of neighborhoods, both perceived and real (Drewnowski, et al. 2014; Drewnowski, et al. 2015) are captured by single measure of

RESULTS

Participants

Participant characteristics are shown in Table 1. Respondents were largely women (62%), 55 years or older (55%), and White (85%). Most respondents (84%) owned their current place of residence. In terms of SES indicators, more than half were college graduates (58%), and had annual household incomes of >\$50,000 (62%).

Mean HEI-2005 score for the sample was relatively high (69.7) compared to the national average of 58.5 based on NHANES 2001–02 (Rehm, et al. 2011). Women had higher quality diets than men (p-value <0.0001). Following national trends (Rehm, et al. 2011), participants with higher education, higher incomes, or those living in higher value homes

had higher HEI 2005 scores in this sample ($p < 0.05$ for each). Similar but stronger trends were observed for HEI-2010 scores. There was little difference in HEI scores by race/ethnicity.

Table 2 shows the relation between tertiles of tax parcel property values and each of the key socio-demographic variables. Higher education and incomes were linked to living in higher-value homes overall; however, the agreement across these three SES measures was not 100%. Residents of homes in the top tertile of property values were mostly college educated (75.2%) but only half (49.6%) had household incomes $\geq 100K$. Residents of homes in the bottom tertile of property values were less likely to be college educated (41.6%) but 9% had household incomes of $\geq 100K$. Persons in the bottom tertile of property values were more likely to be younger and renters than were residents of higher value properties. No significant trends were observed by gender or race/ethnicity.

Table 3 shows multivariable regression results of the three SES measures with HEI-2005 and HEI-2010 scores. All three measures of SES (education, income and residential property values) showed significant positive associations with HEI-2005 scores, adjusted for demographics and home ownership (Table 3A, **Model 1**). In **Model 2**, after adding income and education together in the model, education remained significantly associated with HEI 2005 scores (mean diff = 3.70; 95% CI: 1.91-5.50 among college graduates), while the relation with income became statistically insignificant. In **Model 3**, after adding education and residential property values together, both of these measures remained independently and significantly associated with HEI 2005 scores. However, education had a relatively stronger association (mean diff: 3.36; 95% CI: 1.59, 5.14 among college graduates) compared to the highest tertile of property values (mean diff: 2.51; 95% CI: 0.99, 4.04). Comparing across models, AIC criteria was lowest (8216.2) and adjusted R^2 (0.081) was highest for Model 3, indicating that Model 3, with education and residential property value, provided values was the best model fit in relation to HEI-2005 scores.

Very similar but stronger associations were observed with HEI-2010 scores (Table 3B). Education, income, and residential property values were significantly associated with higher HEI-2010 scores, adjusting for demographics and home ownership (**Model 1**). The relation between HEI 2010 and property values remained significant in **Model 2 and 3**, even after adjusting for education. Based on the AIC criteria and adjusted R^2 values, Model 3 with education and residential property values as SES measures provided the best model fit.

These regression results were then used to map HEI-2005 and 2010 scores across Seattle-King County at census block level (Figure 2). Figure 2A shows the geographic distribution of HEI-2005 for King County, and Figure 2B shows the same data for Seattle. The modeled maps clearly illustrate the geographic gradient in diet quality across census blocks with low and high mean residential property values. Similar geographic gradients are illustrated for HEI-2010 scores at census block level in Figures 3A and B for King County, and Seattle respectively. Appendix 2 and 3 show means, SEMs, and ranges for deciles of property values of SOS participants for HEI-2005 and 2010 respectively. Linear regression analyses between deciles of property values and HEI scores showed significant differences in diet quality between the bottom and the top deciles.

DISCUSSION

The present study is one of the first studies, to our knowledge, to link residential property values, an objective measure of SES or wealth, with diet quality. It also represents the first illustration of the geographic distribution of federal measures of diet quality at the census block level. Several past studies have made the point that diet quality varies across socioeconomic groups and may contribute to spatial disparities in health (Darmon and Drewnowski 2008; Wang, et al. 2014). This study complements prior data by providing the first visual exploration of gradient in HEI-2005 and 2010 scores using novel GIS techniques.

Residential property values at the tax parcel level offer an objective measure of individual SES that may complement the existing self-reports of education and income. First, residential property values were not completely concordant with income categories or with educational attainment. In the SOS sample, almost 50% of the respondents with lower education lived in higher-value homes, whereas almost 25% of those with college degree or more lived in lower value homes. Similar discordance was observed with income. Only half of the respondents living in higher -value homes belonged to highest income category (> \$100,000). Further, households with annual income \$50–<100K were residing in houses with entire range of property value from low to high. These findings imply that residential property values may tap into those dimensions of SES, which are not fully captured by the twin variables of education and income.

The use of residential property values in studies of diets and health is new and offers several advantages. First, missing income data is a common problem as study participants may refuse to answer questions about material assets. Second, tax parcel property values, an objective measure, may reflect accumulated assets and net worth whereas current incomes may be lowered by unemployment or retirement (Braveman, et al. 2005; Krieger, et al. 1997; Moudon, et al. 2011; Rehm, et al. 2012), home equity in the US was the second source of wealth after stocks and bonds (Di, et al. 2003). Past studies on net worth have probed for self-reported data liquid assets (Fonda, et al. 2004; Hajat, et al. 2010; Robert and House 1996) or car or home ownership (Macintyre, et al. 1998; Macintyre, et al. 2003; Sundquist and Johansson 1997) all obtained by self-report. Higher SES groups are characterized by higher economic standing and greater access to resources and services (Abramson, et al. 1982; Berkman and Macintyre 1997; Braveman, et al. 2005; Krieger, et al. 1997; Liberatos, et al. 1988; Macintyre, et al. 1998). These multidimensional constructs may not be fully captured by the standard measures of occupation, education, and income (Braveman, et al. 2005; Krieger, et al. 1997; Moudon, et al. 2011). Third, property value tied to a specific geographic location (tax parcel lot) is a geo-localized measure of SES. While past measures of diet quality have explored the food environment around each participant's census tract or home (Caspi, et al. 2012; McKinnon, et al. 2009; Moore, et al. 2009; Moore, et al. 2008), the present modeling of diet quality by residential property values is new. The geographic distribution of diet quality and food patterns at the much finer scale than done previously can be useful for the targeting of dietary intervention programs by health jurisdictions. This approach has a huge potential in the new field of spatial nutritional epidemiology.

The study had limitations. First, all dietary intake measures were obtained by self-report, in this case the food frequency questionnaire. Second, the cross-sectional nature of the SOS limited our ability to draw any causal inferences between residential property values and diet quality. Furthermore, the use of property values limits the applicability of this method to such populations as shelter dwellers and residents of institutional facilities. However, those populations would not have been a part of the sampling frame for the SOS. Third, the geographic mapping of diet quality, based on a representative but small sample (1,116) of King County adults, did not take full advantage of other census variables beyond property values. However, the present mapping of HEI by census block residential property values illustrates the potential use of residential property value measure to study geographic distribution of diets and health at a very granular level. Third, the population of Seattle and King County is relatively more affluent and educated than the national norm, which may explain higher HEI scores observed in this sample as compared to national figures. The present findings need to be replicated in other parts of the US with a wider distribution of HEI scores and SES variables. We speculate that the present findings would be much stronger with such samples. Fourth, further studies are needed to establish residential property values as an objective measure of long-term SES or wealth for use in health studies.

CONCLUSION

Residential property values may capture socioeconomic disparities better than the conventional measures of education and income. Ability to geo-localize residential property values opens the door to valuable studies on the geography of diets and health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

- Abramson JH, et al. Indicators of social class. A comparative appraisal of measures for use in epidemiological studies. *Soc Sci Med*. 1982; 16(20):1739–1746. [PubMed: 7178920]
- Acar Tek N, et al. Evaluation of dietary quality of adolescents using Healthy Eating Index. *Nutr Res Pract*. 2011; 5(4):322–328. [PubMed: 21994527]
- Aggarwal A, et al. Does diet cost mediate the relation between socioeconomic position and diet quality? *Eur J Clin Nutr*. 2011; 65(9):1059–1066. [PubMed: 21559042]
- Ballas D, et al. Using geographical information systems and spatial microsimulation for the analysis of health inequalities. *Health Informatics J*. 2006; 12(1):65–79. [PubMed: 17023399]
- Berkman LF, Macintyre S. The measurement of social class in health studies: old measures and new formulations. *IARC Sci Publ*. 1997; (138):51–64. [PubMed: 9353663]

- Braveman PA, et al. Socioeconomic status in health research: one size does not fit all. *JAMA*. 2005; 294(22):2879–2888. [PubMed: 16352796]
- Caspi CE, et al. The local food environment and diet: A systematic review. *Health Place*. 2012; 18(5): 1172–1187. [PubMed: 22717379]
- Darmon N, Drewnowski A. Does social class predict diet quality? *Am J Clin Nutr*. 2008; 87(5):1107–1117. [PubMed: 18469226]
- Di ZX, Yang Y, Liu X. The importance of housing to the accumulation of household net worth. Joint Center for Housing Studies Harvard University. 2003; 2014
- Drewnowski A, et al. Obesity and supermarket access: proximity or price? *Am J Public Health*. 2012; 102(8):e74–e80. [PubMed: 22698052]
- Drewnowski A, et al. Environments perceived as obesogenic have lower residential property values. *Am J Prev Med*. 2014; 47(3):260–274. [PubMed: 25049218]
- Drewnowski A, et al. Residential property values predict prevalent obesity but do not predict 1-year weight change. *Obesity (Silver Spring)*. 2015; 23(3):671–676. [PubMed: 25684713]
- Drewnowski A, Darmon N. The economics of obesity: dietary energy density and energy cost. *Am J Clin Nutr*. 2005; 82(1 Suppl):265s–273s. [PubMed: 16002835]
- Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. *Am J Clin Nutr*. 2004; 79(1):6–16. [PubMed: 14684391]
- Edwards KL, Clarke GP. The design and validation of a spatial microsimulation model of obesogenic environments for children in Leeds, UK: SimObesity. *Soc Sci Med*. 2009; 69(7):1127–1134. [PubMed: 19692160]
- Ervin RB. Healthy Eating Index-2005 total and component scores for adults aged 20 and over: National Health and Nutrition Examination Survey, 2003–2004. *Natl Health Stat Report*. 2011; (44):1–9. [PubMed: 22432250]
- Fonda SJ, et al. Relationship of body mass and net worth for retirement-aged men and women. *Research on Aging*. 2004; 26(1):153–176.
- Galea S, et al. Estimated deaths attributable to social factors in the United States. *Am J Public Health*. 2011; 101(8):1456–1465. [PubMed: 21680937]
- Galobardes B, Morabia A, Bernstein MS. Diet and socioeconomic position: does the use of different indicators matter? *Int J Epidemiol*. 2001; 30(2):334–340. [PubMed: 11369739]
- Groth MV, Fagt S, Brondsted L. Social determinants of dietary habits in Denmark. *Eur J Clin Nutr*. 2001; 55(11):959–966. [PubMed: 11641744]
- Guenther PM, et al. Update of the Healthy Eating Index: HEI-2010. *J Acad Nutr Diet*. 2013; 113(4): 569–580. [PubMed: 23415502]
- Guenther, PM., et al. Healthy Eating Index-2005. Vol. 2013. Alexandria, VA: USDA Center for Nutrition Policy and Promotion; 2005.
- Hackett A, et al. Mapping dietary habits may provide clues about the factors that determine food choice. *J Hum Nutr Diet*. 2008; 21(5):428–437. [PubMed: 18647211]
- Hajat A, et al. Do the wealthy have a health advantage? Cardiovascular disease risk factors and wealth. *Soc Sci Med*. 2010; 71(11):1935–1942. [PubMed: 20970902]
- Hulshof KF, et al. Socio-economic status, dietary intake and 10 y trends: the Dutch National Food Consumption Survey. *Eur J Clin Nutr*. 2003; 57(1):128–137. [PubMed: 12548307]
- Kant AK, Graubard BI. Secular trends in the association of socio-economic position with self-reported dietary attributes and biomarkers in the US population: National Health and Nutrition Examination Survey (NHANES) 1971–1975 to NHANES 1999–2002. *Public Health Nutr*. 2007; 10(2):158–167. [PubMed: 17261225]
- Keller HH, Ostbye T, Bright-See E. Predictors of dietary intake in Ontario seniors. *Can J Public Health*. 1997; 88(5):305–309. [PubMed: 9401163]
- Krieger N, et al. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: the Public Health Disparities Geocoding Project. *Am J Public Health*. 2005; 95(2):312–323. [PubMed: 15671470]
- Krieger N, Williams DR, Moss NE. Measuring social class in US public health research: concepts, methodologies, and guidelines. *Annu Rev Public Health*. 1997; 18:341–378. [PubMed: 9143723]

- Kushi LH, et al. Educational attainment and nutrient consumption patterns: the Minnesota Heart Survey. *J Am Diet Assoc.* 1988; 88(10):1230–1236. [PubMed: 2844877]
- Lallukka T, et al. Multiple socio-economic circumstances and healthy food habits. *Eur J Clin Nutr.* 2007; 61(6):701–710. [PubMed: 17180154]
- Liberatos P, Link BG, Kelsey JL. The measurement of social class in epidemiology. *Epidemiol Rev.* 1988; 10:87–121. [PubMed: 3066632]
- Lucan SC, Mitra N. The food environment and dietary intake: demonstrating a method for GIS-mapping and policy-relevant research. *Journal of Public Health.* 2011; 20(4):375–385.
- Macintyre S, et al. Do housing tenure and car access predict health because they are simply markers of income or self esteem? A Scottish study. *J Epidemiol Community Health.* 1998; 52(10):657–664. [PubMed: 10023466]
- Macintyre S, et al. Socio-economic position and health: what you observe depends on how you measure it. *J Public Health Med.* 2003; 25(4):288–294. [PubMed: 14747587]
- Marmot M. Social determinants of health inequalities. *Lancet.* 2005; 365(9464):1099–1104. [PubMed: 15781105]
- McKinnon RA, et al. Measures of the food environment: a compilation of the literature, 1990–2007. *Am J Prev Med.* 2009; 36(4 Suppl):S124–S133. [PubMed: 19285203]
- Monsivais P, Drewnowski A. Lower-energy-density diets are associated with higher monetary costs per kilocalorie and are consumed by women of higher socioeconomic status. *J Am Diet Assoc.* 2009; 109(5):814–822. [PubMed: 19394467]
- Moore LV, et al. Fast-food consumption, diet quality, and neighborhood exposure to fast food: the multi-ethnic study of atherosclerosis. *Am J Epidemiol.* 2009; 170(1):29–36. [PubMed: 19429879]
- Moore LV, et al. Associations of the local food environment with diet quality—a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. *Am J Epidemiol.* 2008; 167(8):917–924. [PubMed: 18304960]
- Moudon AV, et al. A neighborhood wealth metric for use in health studies. *Am J Prev Med.* 2011; 41(1):88–97. [PubMed: 21665069]
- Neuhouser ML, et al. Validity of short food frequency questionnaires used in cancer chemoprevention trials: results from the Prostate Cancer Prevention Trial. *Cancer Epidemiol Biomarkers Prev.* 1999; 8(8):721–725. [PubMed: 10744133]
- Ogden CL, et al. Obesity and socioeconomic status in adults: United States, 2005–2008. *NCHS Data Brief.* 2010; (50):1–8.
- Patterson RE, et al. Measurement characteristics of the Women's Health Initiative food frequency questionnaire. *Ann Epidemiol.* 1999; 9(3):178–187. [PubMed: 10192650]
- Penney TL, et al. A spatial analysis of community level overweight and obesity. *J Hum Nutr Diet.* 2014; 27(Suppl 2):65–74. [PubMed: 23701323]
- Pollack CE, et al. Should health studies measure wealth? A systematic review. *Am J Prev Med.* 2007; 33(3):250–264. [PubMed: 17826585]
- Rahmanian E, et al. The association between the built environment and dietary intake - a systematic review. *Asia Pac J Clin Nutr.* 2014; 23(2):183–196. [PubMed: 24901086]
- Raja, Samina; Ma, Changxing; Yadav, Pavan. Beyond food deserts: Measuring and mapping racial disparities in neighborhood food environments. *Journal of Planning Education and Research.* 2008; 27:469–482.
- Rehm CD, Monsivais P, Drewnowski A. The quality and monetary value of diets consumed by adults in the United States. *Am J Clin Nutr.* 2011; 94(5):1333–1339. [PubMed: 21918223]
- Rehm CD, et al. Residential property values are associated with obesity among women in King County, WA, USA. *Soc Sci Med.* 2012; 75(3):491–495. [PubMed: 22591823]
- Rehm CD, Monsivais P, Drewnowski A. Relation between diet cost and Healthy Eating Index 2010 scores among adults in the United States 2007–2010. *Prev Med.* 2015; 73:70–75. [PubMed: 25625693]
- Ricciuto LE, Tarasuk VS. An examination of income-related disparities in the nutritional quality of food selections among Canadian households from 1986–2001. *Soc Sci Med.* 2007; 64(1):186–198. [PubMed: 17030372]

- Rimm EB, et al. Vitamin E consumption and the risk of coronary heart disease in men. *N Engl J Med.* 1993; 328(20):1450–1456. [PubMed: 8479464]
- Robert S, House JS. SES differentials in health by age and alternative indicators of SES. *J Aging Health.* 1996; 8(3):359–388. [PubMed: 10165980]
- Stampfer MJ, et al. Vitamin E consumption and the risk of coronary disease in women. *N Engl J Med.* 1993; 328(20):1444–1449. [PubMed: 8479463]
- Sundquist J, Johansson SE. Indicators of socio-economic position and their relation to mortality in Sweden. *Soc Sci Med.* 1997; 45(12):1757–1766. [PubMed: 9447626]
- Wang DD, et al. Trends in dietary quality among adults in the United States, 1999 through 2010. *JAMA Intern Med.* 2014; 174(10):1587–1595. [PubMed: 25179639]
- Wang Y, Zhang Q. Are American children and adolescents of low socioeconomic status at increased risk of obesity? Changes in the association between overweight and family income between 1971 and 2002. *Am J Clin Nutr.* 2006; 84(4):707–716. [PubMed: 17023695]
- Zhang Q, Wang Y. Trends in the association between obesity and socioeconomic status in U.S. adults: 1971 to 2000. *Obes Res.* 2004; 12(10):1622–1632. [PubMed: 15536226]

Highlights

- Measures of diet quality and health follow a socio-economic gradient
- The use of property values provides a geo-localized index of socioeconomic status
- SES indicators at a fine geographic scale permit the mapping of social disparities
- This paper provides the first map of Healthy Eating Index at census block level

a

b

Figure 1.
Geographic distribution of tax parcel residential property values at the census block level at the tax parcel for King County (A), and for Seattle (B)

a

b

Figure 2.
Geographic distribution of healthy eating index 2005 (HEI-2005) at the census block level for King County (A), and for Seattle (B)

a

b

Figure 3.
Geographic distribution of healthy eating index 2010 (HEI-2010) at the census block level for King County (A), and for Seattle (B)

Table 1
Sample distribution by healthy eating index, a federal measure of diet quality (HEI-2005 and HEI-2010 scores)

	TOTAL	HEI-2005	HEI-2010
	N (%)	Mean (SD)	Mean (SD)
OVERALL	1116 (100.0)	69.7 (10.0)	71.2 (9.9)
Gender			
Male	420 (37.6)	66.7 (10.4)	68.9 (10.6)
Female	696 (62.4)	71.5 (9.2)	72.6 (9.2)
Age			
18 to 44	242 (21.7)	69.6 (9.1)	69.7 (8.9)
45 to 54	257 (23.0)	69.2 (9.9)	71.1 (9.6)
55 to 64	325 (29.1)	69.4 (10.1)	71.6 (9.7)
65 or older	292 (26.2)	70.4 (10.5)	72.1 (10.9)
Race and Ethnicity			
White, Non-Hispanic	977 (87.5)	69.6 (10.1)	71.4 (9.9)
Others	139 (12.5)	70.1 (9.3)	70.2 (9.6)
Own or Rent Current Residence			
Own	936 (83.9)	70.0 (9.8)	71.7 (9.7)
Rent	180 (16.1)	68.0 (10.9)	68.7 (10.7)
Education			
High School graduate or less	185 (16.6)	67.1 (10.9)	68.2 (11.1)
Some college or technical school	283 (25.4)	68.8 (10.9)	70.3 (10.7)
College Graduate or higher	648 (58.1)	70.8 (9.1)	72.5 (8.9)
Annual Household Income			
< \$50,000	424 (38.0)	68.9 (10.5)	70.0 (10.4)
\$50,000 to \$99,999	400 (35.8)	69.8 (10.2)	71.5 (10.2)
\$100,000	292 (26.2)	70.5 (8.7)	72.7 (8.5)
Residential property values at tax parcel			
Low (\$19,907–\$234,949)	368 (33.0)	67.8 (10.6)	68.9 (10.4)
Medium (\$234,950–\$340,000)	369 (33.1)	69.9 (9.8)	71.2 (9.9)
High (\$340,000–\$2,440,000)	379 (34.0)	71.2 (9.2)	73.4 (8.8)

stents are column percents

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Table 2

Unadjusted associations between residential property values and key socio-demographic variables

	Residential Property Values			<i>P</i> Value
	Low N (%)	Medium N (%)	High N (%)	
Sex				
Male	138 (37.5)	143 (38.8)	139 (36.7)	0.840
Female	230 (62.5)	226 (61.2)	240 (63.3)	
Age				
18 to 44	98 (26.6)	83 (22.5)	61 (16.1)	<0.001
45 to 54	79 (21.5)	92 (24.9)	86 (22.7)	
55 to 64	81 (22.0)	108 (29.3)	136 (35.9)	
65 or older	110 (29.9)	86 (23.3)	96 (25.3)	
Race and Ethnicity				
White, Non-Hispanic	316 (85.9)	298 (80.8)	335 (88.4)	0.053
Black	29 (7.9)	47 (12.7)	29 (7.7)	
Asian	8 (2.2)	6 (1.6)	2 (0.5)	
Other	15 (4.1)	18 (4.9)	13 (3.4)	
Own or Rent Current Residence				
Own	240 (65.2)	340 (92.1)	356 (93.9)	<0.001
Rent	128 (34.8)	29 (7.9)	23 (6.1)	
Education				
High School graduate or less	92 (25.0)	62 (16.8)	31 (8.2)	<0.001
Some college or technical school	123 (33.4)	97 (26.3)	63 (16.6)	
College Graduate or higher	153 (41.6)	210 (56.9)	285 (75.2)	
Annual Household Income				
< \$50,000	220 (59.8)	125 (33.9)	79 (20.8)	<0.001
\$50,000 to \$99,999	115 (31.3)	173 (46.9)	112 (29.6)	
\$100,000	33 (9.0)	71 (19.2)	188 (49.6)	

*
Column percents

Table 3

A. Multivariable regression analyses to compare three SES measures - income, education and residential property values in relation to healthy eating index (HEI-2005)

	Model 1			Model 2			Model 3					
	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²
STANDARD SES MEASURES												
Education												
High School graduate or less	Ref	8223.1	0.080	0.074	Ref	8218.1	0.083	0.074	Ref	8216.2	0.089	0.081
Some college or technical school	1.83 (−0.14, 3.81)				1.80 (−0.18, 3.78)				1.71 (−0.24, 3.67)			
College Grad or higher	3.99 (2.23, 5.75)				3.70 (1.91, 5.50)				3.36 (1.59, 5.14)			
Annual Household Income												
< \$50K	Ref	8235.2	0.066	0.058	Ref							
\$50K to <100K	1.28 (−0.17, 2.74)				0.72 (−0.73, 2.19)							
\$100K	2.34 (0.80, 3.89)				1.30 (−0.28, 2.89)							
NEW SES MEASURE												
Residential property values at tax parcel												
Low	Ref	8229.3	0.075	0.067					Ref			
Medium	2.08 (0.61, 3.54)								1.70 (0.23, 3.17)			
High	3.38 (1.92, 4.83)								2.51 (0.99, 4.04)			

B. Multivariable regression analyses to compare three SES measures - income, education and residential property values in relation to healthy eating index (HEI-2010)

	Model 1			Model 2			Model 3					
	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²
STANDARD SES/MEASURES												
Education												
High School graduate or less	Ref	8215.1	0.080	0.073	Ref	8205.7	0.087	0.078	Ref	8202.8	0.093	0.085
Some college or technical school	2.34 (0.32, 4.35)				2.23 (0.22, 4.24)				2.19 (0.19, 4.18)			
College Grad or higher	4.76 (2.94, 6.58)				4.20 (2.35, 6.05)				3.97 (2.14, 5.79)			
Annual Household Income												

B. Multivariable regression analyses to compare three SES measures - income, education and residential property values in relation to healthy eating index (HEI-2010)

	Model 1			Model 2			Model 3					
	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²	Mean Diff (95% CI)	AIC [†]	R ²	Adj R ²
< \$50K	Ref	8228.1	0.065	0.058	Ref							
\$50K to <100K	1.94	(0.48, 3.41)			1.34	(−0.13, 2.81)						
\$100K	3.72	(2.17, 5.27)			2.57	(0.96, 4.19)						
NEW SES MEASURE												
Residential property values at tax parcel												
Low	Ref	8222.2	0.074	0.067					Ref			
Medium	2.13	(0.66, 3.60)							1.70	(0.23, 3.16)		
High	4.09	(2.67, 5.51)							3.11	(1.63, 4.58)		

Bold indicates statistical significance at the 0.05 level.

Model 1: Adjusted for individual level sex, age, race (white Non-Hispanic versus other), and home ownership status

Model 2: Model 1+ added education and income in the same model

Model 3: Model 1+ added education and residential property values in the same model

[†] Low Akaike Information Criteria (AIC) indicates best Model Fit