

# A New Metrics Toolbox to Assess the Cost and Geographic Distribution of Healthy Diets

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June 3<sup>rd</sup>, 2017



**SCHOOL OF PUBLIC HEALTH**  
UNIVERSITY *of* WASHINGTON



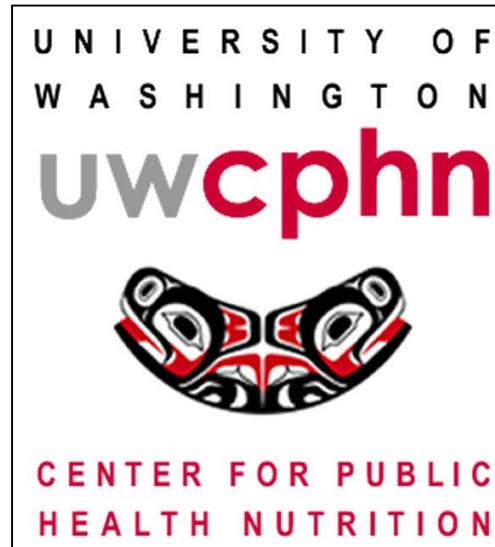
# Aligning food systems with dietary needs

There are multiple drivers of food choices at the consumer level:

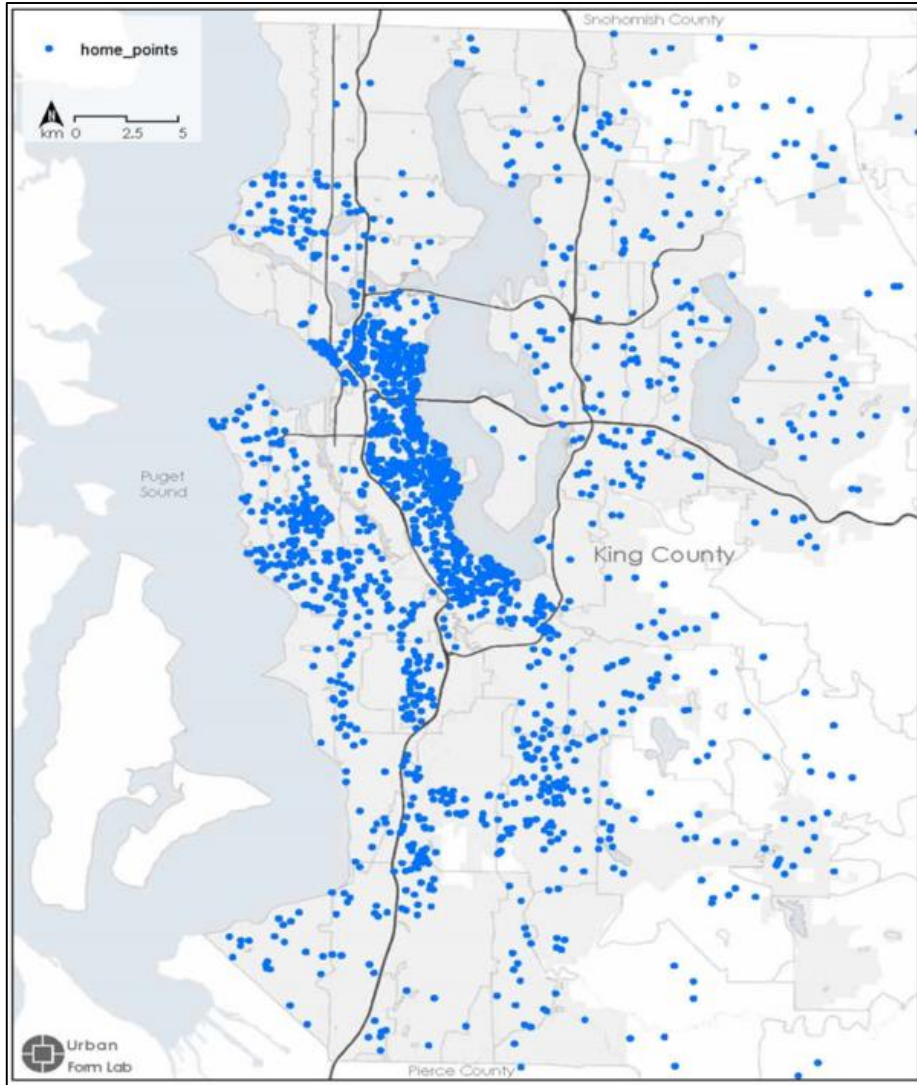
- Economics
- Geographic
- Psychosocial

Each dimension has its metrics and measures.

# The UW Food Environment Research Team



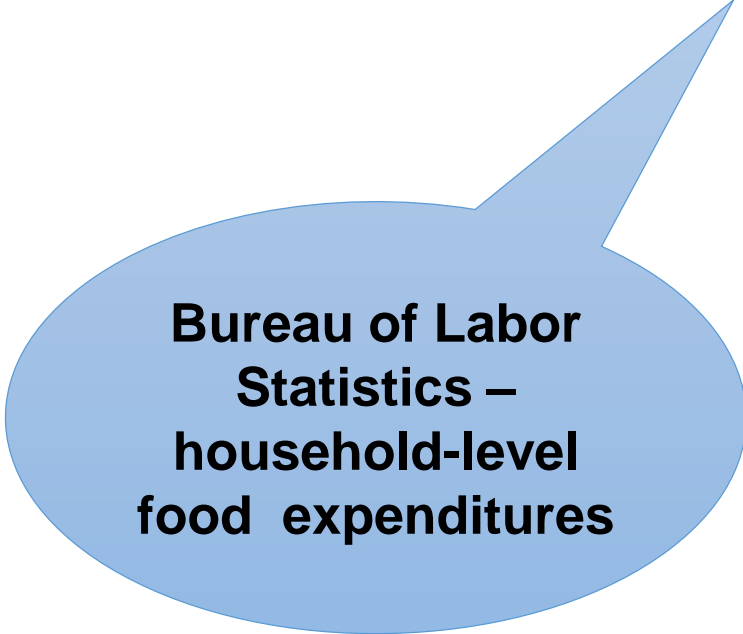
# Seattle Obesity Study (SOS)



- NIDDK R01 076608-10
- SOS I 2008-2011
- SOS II 2011-2015
- SOS III 2015-2020
- King, Pierce and Yakima counties (total N approx 3,500)
- Diets: FFQ and 24-hr recall
- Affordability: market basket
- Geolocation: GIS and GPS
- Attitudes: Questionnaire self-report
- Health outcomes: measured ht/wt
- Goal: Assess drivers of food choice; their interactions and body weight trajectories.

# Economic dimension of food access

Are healthy foods affordable?  
Do healthier diets cost more?



Bureau of Labor  
Statistics –  
household-level  
food expenditures




No data on cost of  
diets at individual-  
level

**A novel way to estimate cost of the diet at the individual-  
level by attaching prices to their diets!**

# Metric #1: Individual-level estimate of diet cost

- Used a standard dietary data collection tool – Food Frequency Questionnaires (FFQ).
- Lowest price, non sale price
- Collected for each of the 384 foods and beverages underlying FFQ.

## Food Questionnaire



This form asks about your usual food intake during \_\_\_\_\_.

Please use **pencil**.

Answer by filling in the correct oval.

Yes     No

Do not make any other marks on the form. Please use a separate piece of paper to make comments.

TODAY'S DATE			IDENTIFICATION NUMBER			
MO	DAY	YEAR				
1	2	3	4	5	6	7
8	9	0	1	2	3	4
5	6	7	8	9	0	1

# Metric #1: Individual-level estimate of diet cost

## How it works?

Attached prices exactly the same way a nutrient vector is attached to the FFQ

**FRUITS**

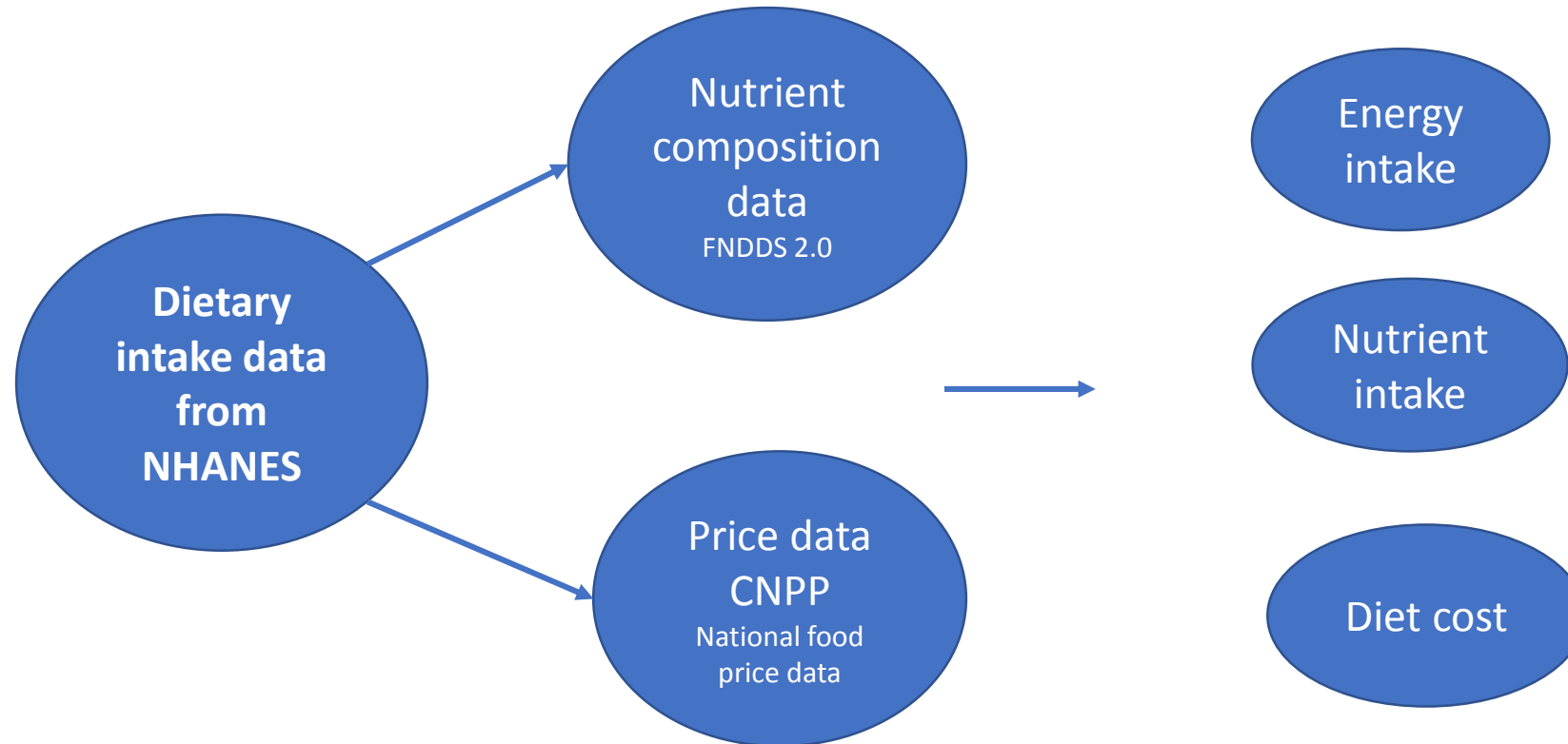
HOW OFTEN DID YOU EAT THESE FOODS? → AMOUNT?

	NEVER or less than once per month	1 per month	2-3 per month	1 per week	2 per week	3-4 per week	5-6 per week	1 per day	2+ per day	Medium serving size	S	M	L
Apples, applesauce and pears	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 medium or 1/2 cup	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Bananas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 medium	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

ID	FFQ weight	Name	shelf price	unit price	\$/lb or pt	\$/100g	Yield	Adjusted Cost (\$/100g)
2001	0.6	Apples, fresh, with skin		1.99/lb	1.99	0.44	0.90	0.49
2003	0.1	Pear, fresh, with skin		1.89/lb	1.89	0.42	0.92	0.45
2004	0.1	Pears, canned	1.44	1.536/lb	1.54	0.34	0.59	0.57
2026	0.2	Applesauce	2.51	1.673/lb	1.67	0.37	1.0	0.37
	1	Composite (weighted average)						0.47



# Metric #1: Individual-level estimate of diet cost

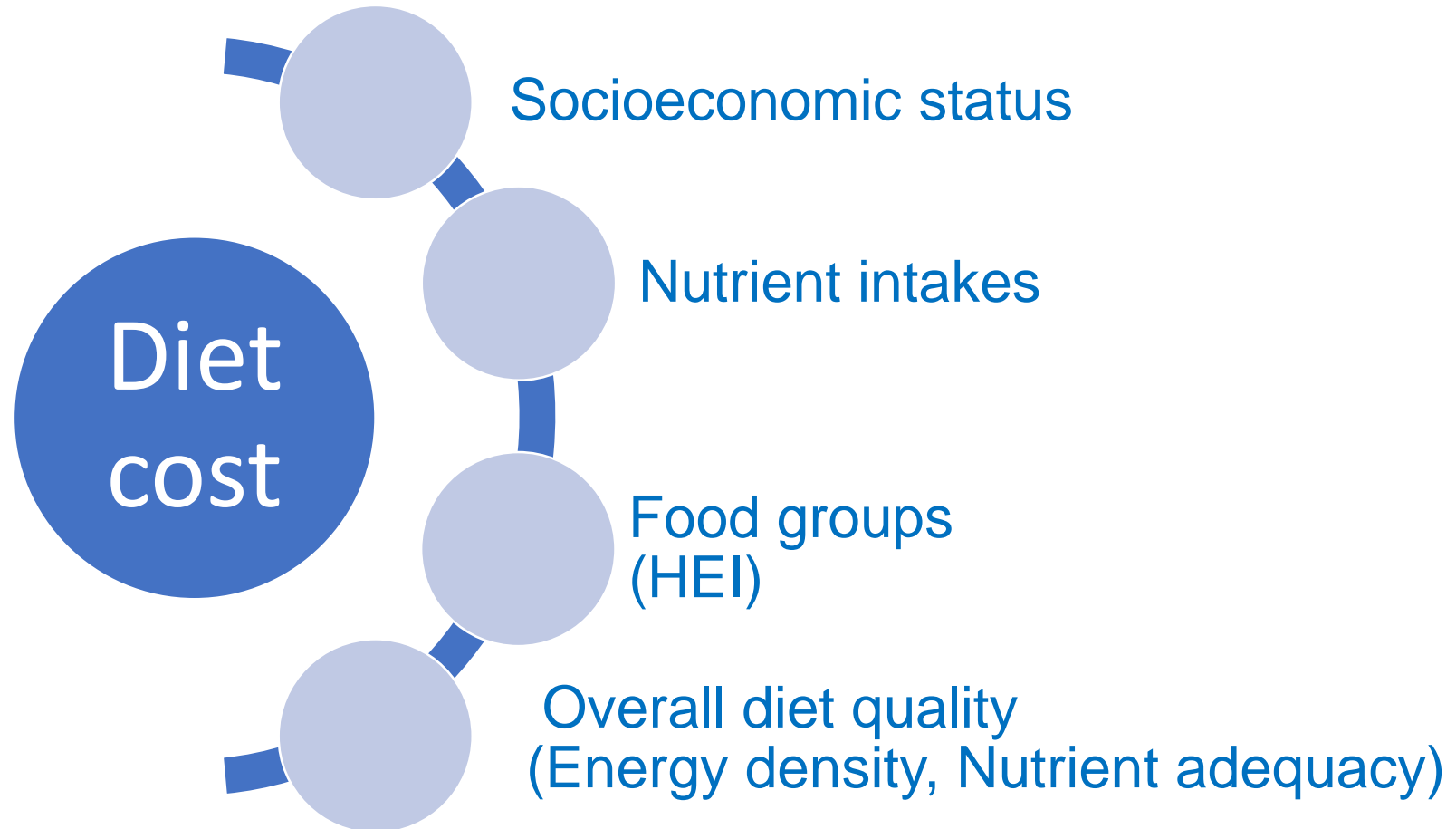


This process yields:

- Average daily intake of calories, grams, and 45 macro- and micro-nutrients for each respondent.
- Estimated cost of the habitual diet for each respondent.

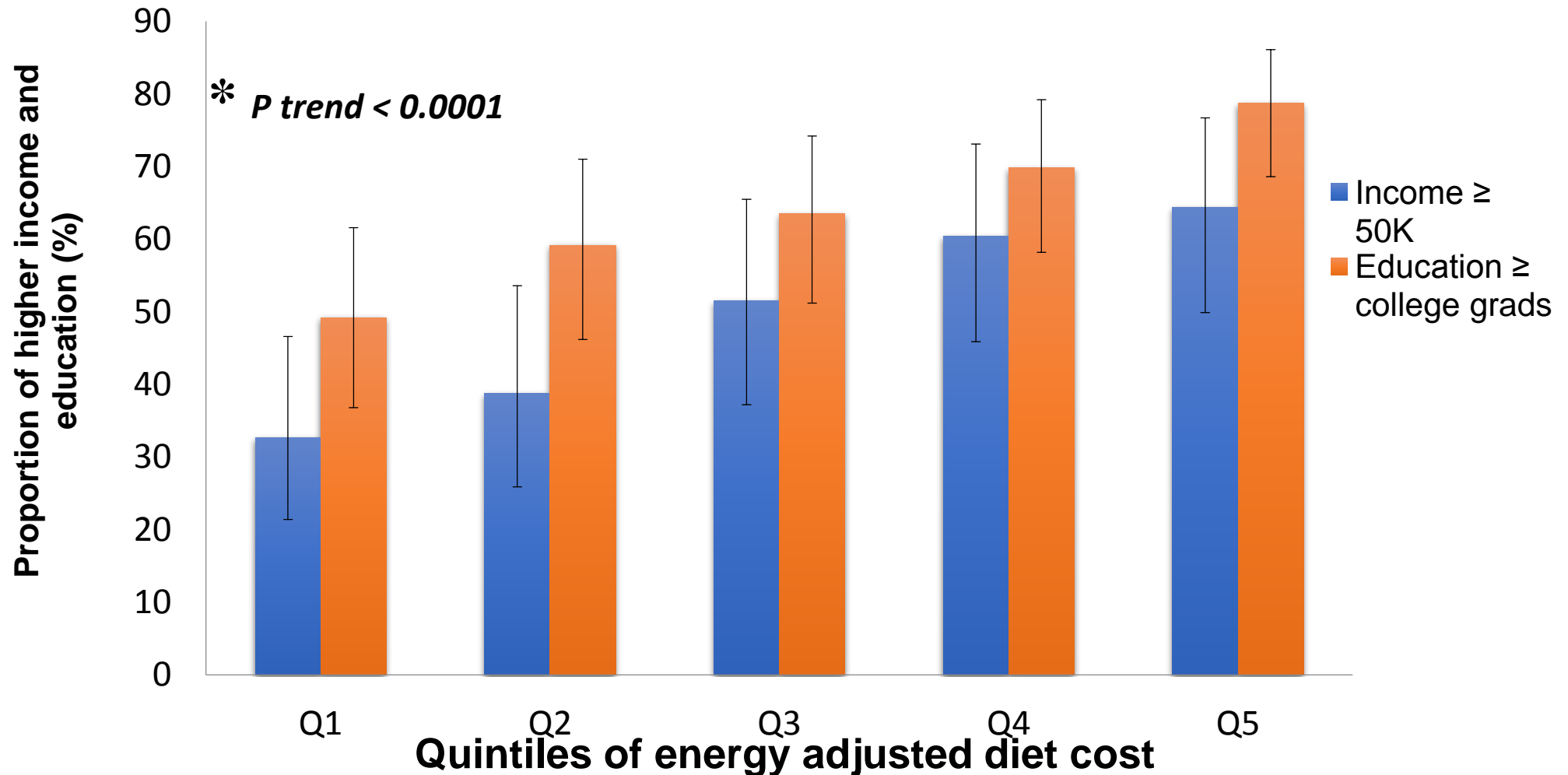


# This technique brings nutrition economics to the field of nutrition epidemiology



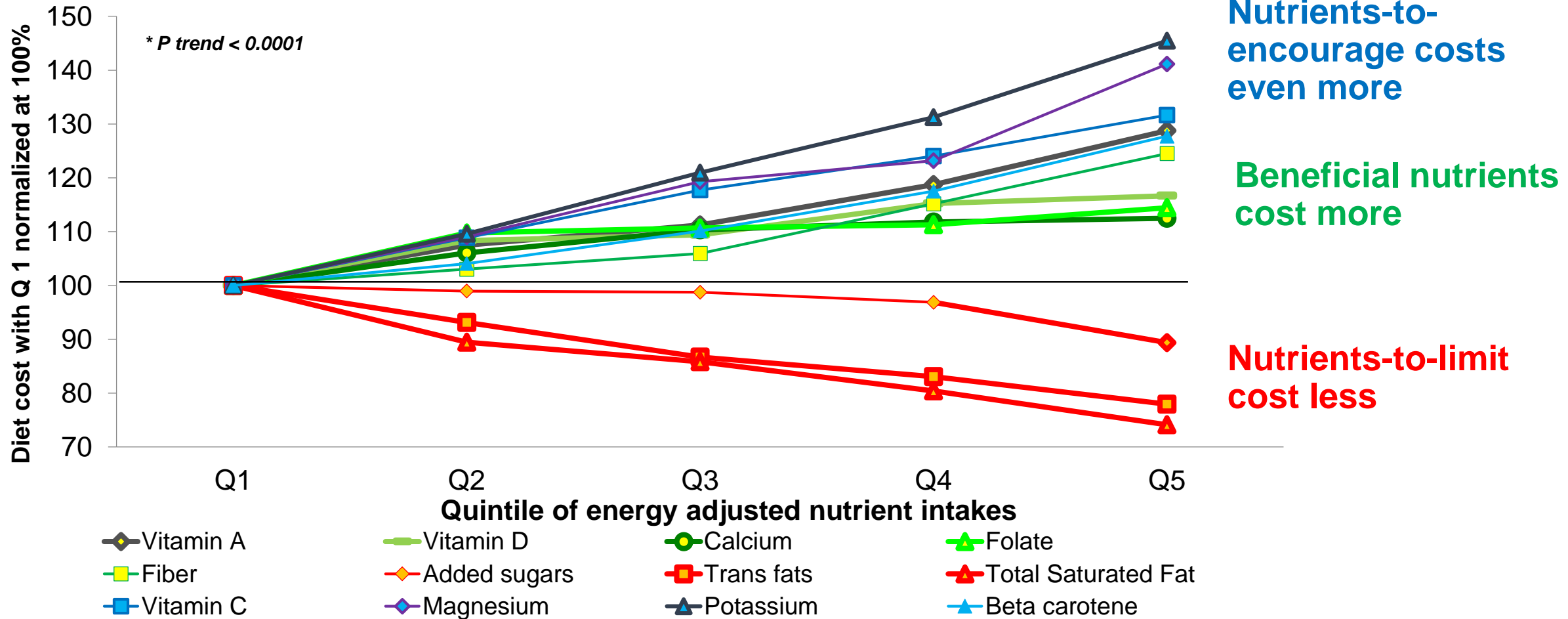
# Diet cost linked to socioeconomic status

Lower cost diets are more likely to be consumed by lower SES



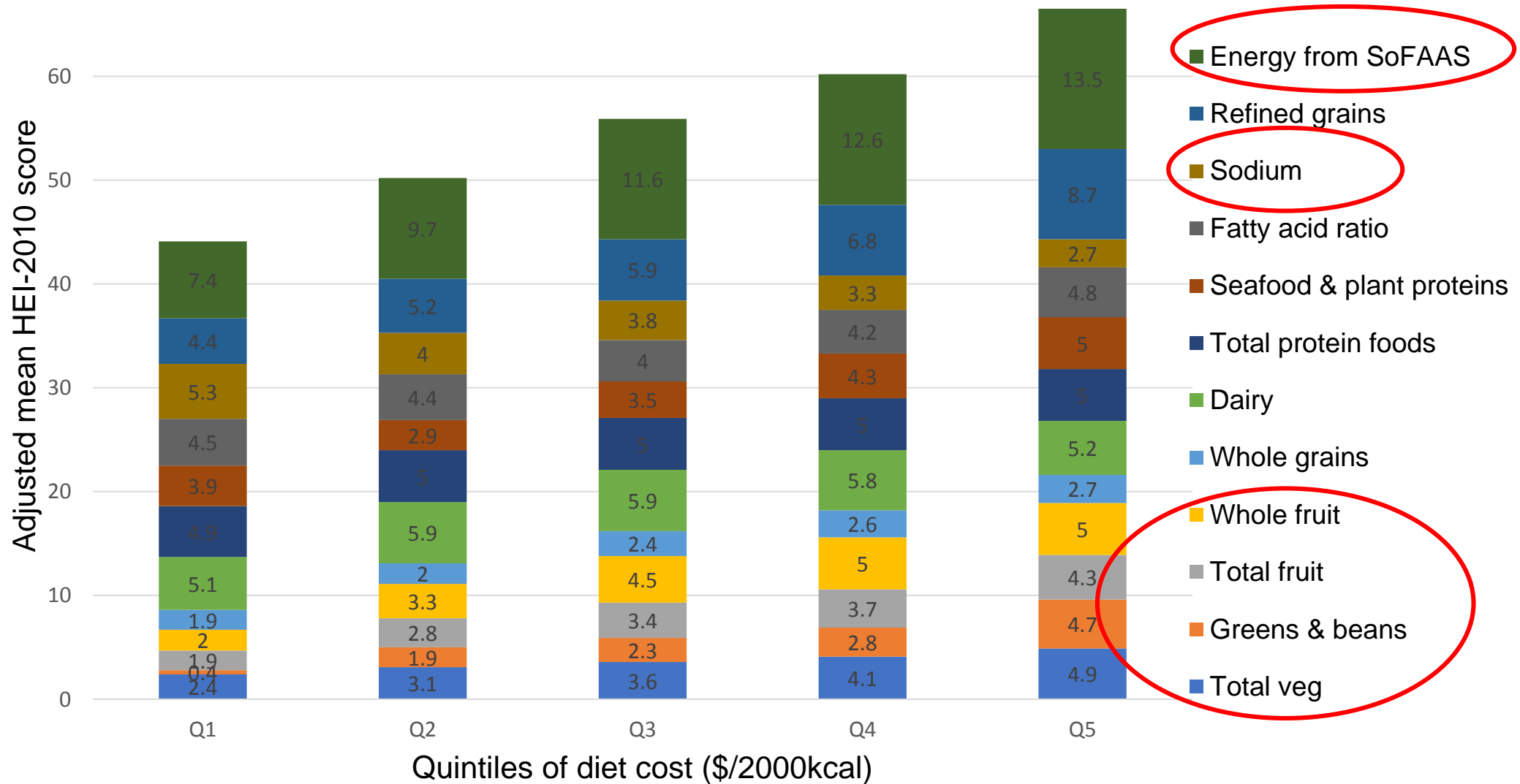
# Diet cost linked to nutrient intakes

## Nutrient rich diets tend to cost more



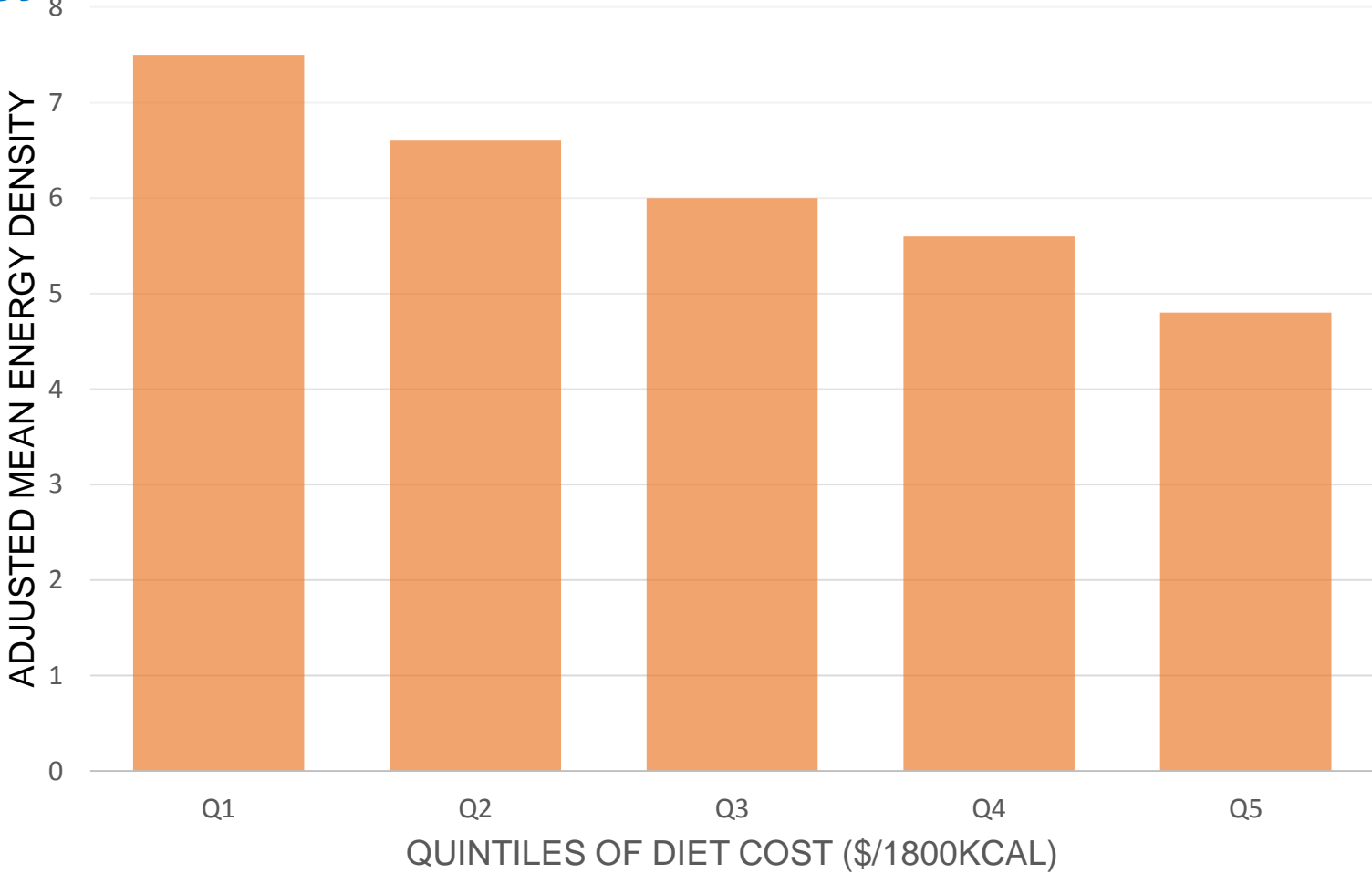
# Diet cost linked to healthy eating index (HEI-2010)

Diets with higher HEI scores tend to cost more



# Diet cost linked to dietary energy density

Energy dense diets tend to cost less



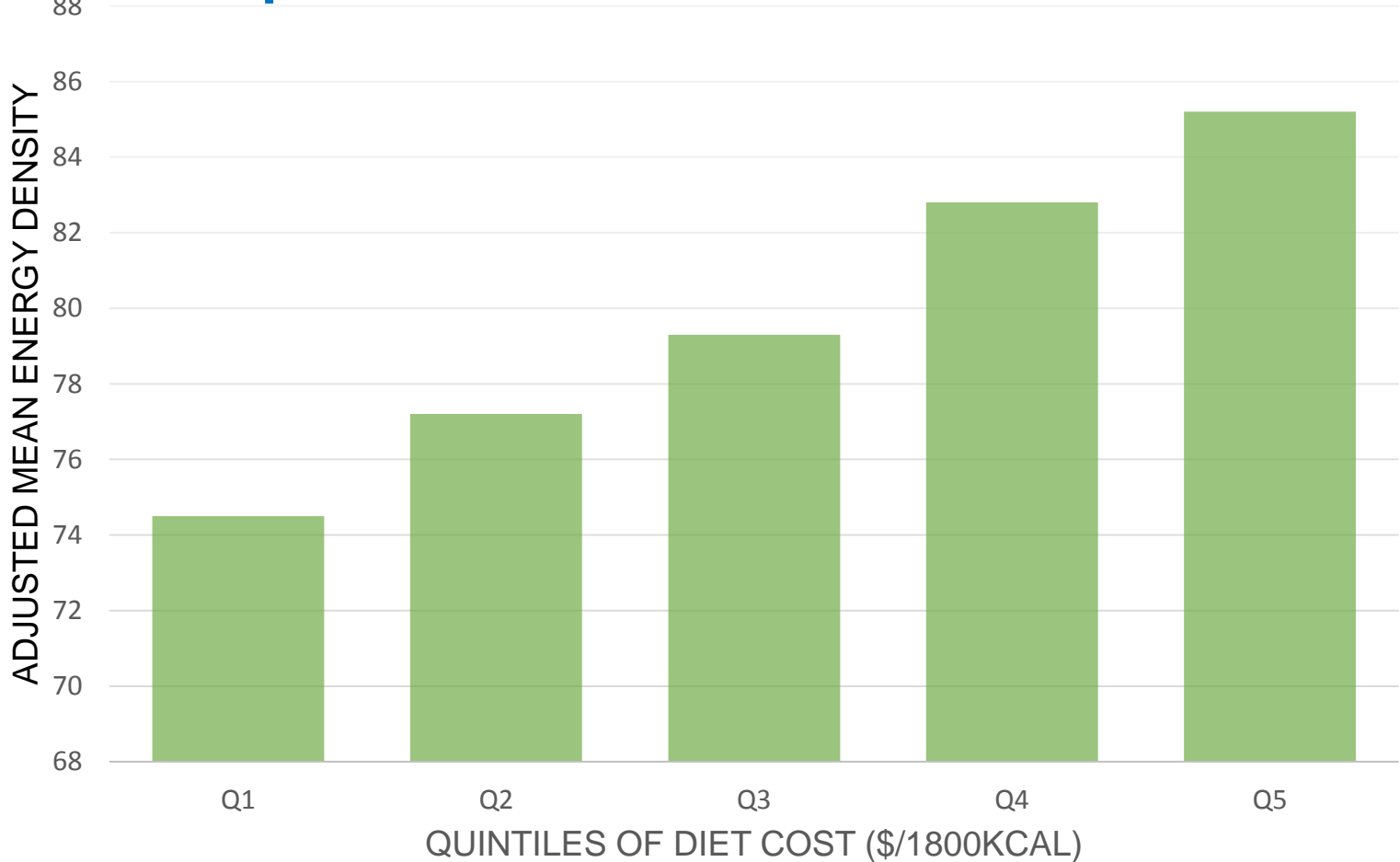
p-value <0.0001

Energy density defined as total calories over grams of foods consumed (Kcal/g)

Source: Aggarwal et al. EJCN 2011. <https://www.ncbi.nlm.nih.gov/pubmed/21559042>

# Diet cost linked to nutrient adequacy (MAR)

## Nutrient adequate diets tend to cost more

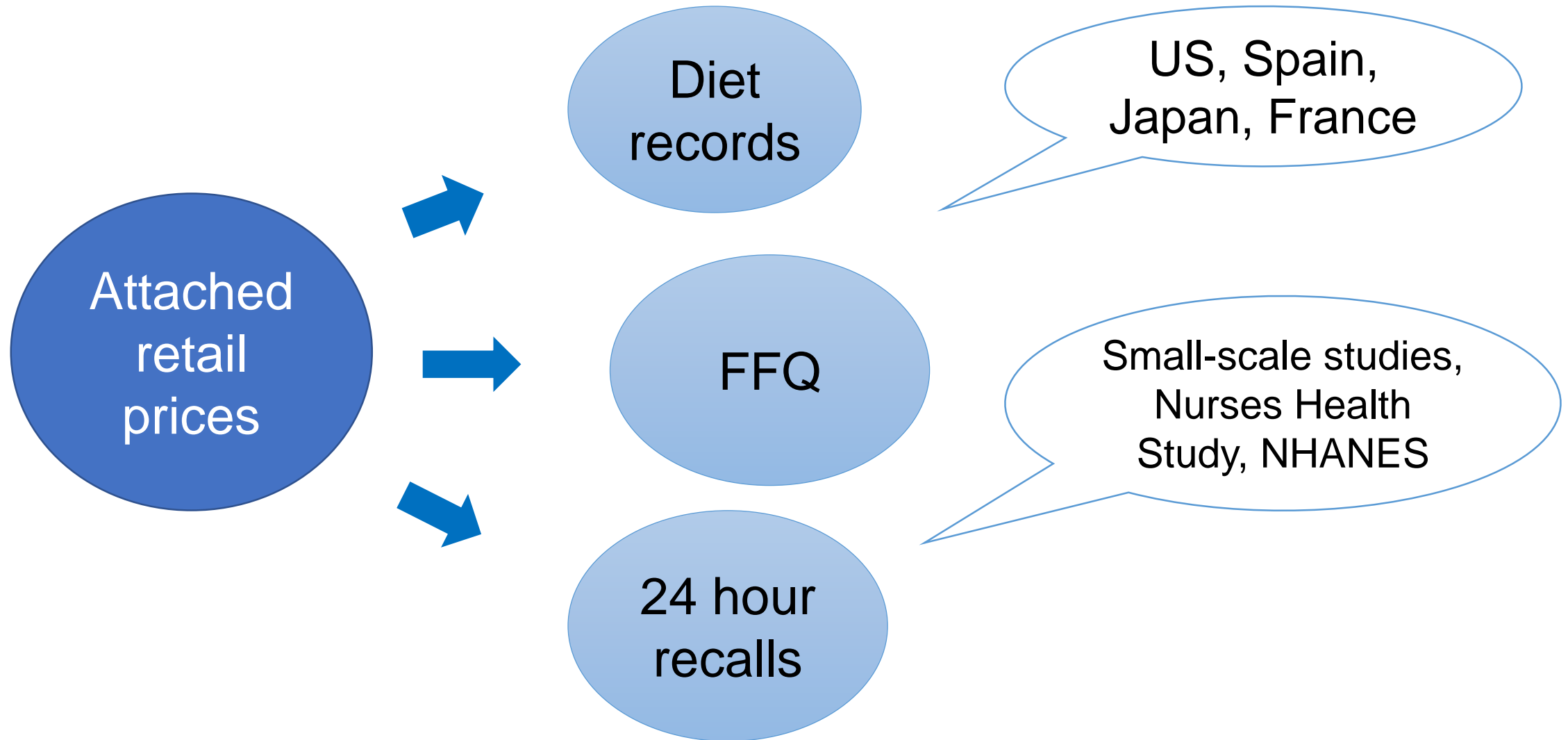


p-value <0.0001

Mean adequacy ratio (MAR) was defined as the truncated index of the percent of daily recommended intakes for key nutrients. Nutrients included Vit A, C, D, E, B12, Calcium, Iron, Magnesium, Potassium, Folate and Fiber

Source: Aggarwal et al. EJCN 2011. <https://www.ncbi.nlm.nih.gov/pubmed/21559042>

# Diet cost estimated from other dietary surveys





# Diet cost and diet quality in French studies

Attached prices to FFQ,  
diet records, year 2000

European Journal of Clinical Nutrition (2006) 60, 434–436  
© 2006 Nature Publishing Group All rights reserved 0954-3007/06 \$30.00  
www.nature.com/ejcn

## SHORT COMMUNICATION

### Low-cost diets: more energy, fewer nutrients

E Andrieu<sup>1</sup>, N Darmon<sup>1</sup> and A Drewnowski<sup>2</sup>

<sup>1</sup>Nutritional Epidemiology Research Unit INSEP, University of Washington  
<sup>2</sup>Community Medicine, University of Washington

Energy-dense diets offer a low-cost dietary option. In a community-based study, based on the French national food cost survey, adult participants were stratified by quartile of energy density. Energy-dense diets and the lowest daily intake of energy-dense foods had lower energy intakes, and diets with the highest energy density had 165% higher costs. In this observational study, energy-dense diets were associated with lower diet costs. *European Journal of Clinical Nutrition* (2006)

**Keywords:** diet cost; energy cost; energy density

[Public Health Nutr](#), 2004 Feb;7(1):21-7.

### Energy-dense diets are associated with lower diet costs: a community study of French adults.

Darmon N<sup>1</sup>, Briand A, Drewnowski A.

#### Author information

#### Abstract

**OBJECTIVE:** High consumption of energy-dense foods has been linked to high energy intakes and excess weight gain. This study tested the hypothesis that high energy density of the total diet is associated with lower diet costs.

**DESIGN:** Dietary intakes of 837 French adults, aged 18–76 years, were assessed using a dietary history method. Dietary energy density (MJ kg<sup>-1</sup>) was calculated by dividing total energy by the edible weight of foods consumed. Daily diet cost (in day<sup>-1</sup>) was estimated using mean national food prices for 57 food items. The relationship between dietary energy density and diet cost at each level of energy intake was examined in a regression model, adjusted for gender and age.

**RESULTS:** The more energy-dense refined grains, sweets and fats provided energy at a lower cost than did lean meats, vegetables and fruit. Within each quintile of energy intake, diets of lower energy density (MJ kg<sup>-1</sup>) were associated with higher diet costs (in day<sup>-1</sup>).

**CONCLUSION:** In this observational study, energy-dense diets cost less whereas energy-dilute diets cost more, adjusting for energy intakes. The finding that energy-dilute diets are associated with higher diet costs has implications for dietary guidelines and current strategies for dietary change.

PMID: 14972068

# SES, diet cost and diet quality studies from the US

European Journal of Clinical Nutrition (2006) 60, 434–436  
© 2006 Nature Publishing Group. All rights reserved. 0954-3007/06 \$30.00

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## Nutrient Intakes Linked to Better Health Outcomes Are Associated with Higher Diet Costs

Anju Aggarwal<sup>1,2\*</sup>, Pablo Monsivais<sup>1,3</sup>, Adam Drewnowski<sup>1,3</sup>

<sup>1</sup>Center for Public Health Nutrition, School of Public Health, University of Washington, Seattle, WA; <sup>2</sup>Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD; <sup>3</sup>Collaboration Centre for Diet and Activity Research, Cambridge Institute of Public Health, Cambridge, UK

**Abstract**

**Purpose:** Degrees of nutrient intake and food groups have been linked to health outcomes. Intakes of specific nutrients may also be associated with differential diet costs and food quality (SES). The present study examined degrees of nutrient intake, for every 10% increase in intake, for every 10% increase in SES.

**Methods:** Socio-demographic data for a stratified random sample of adults were obtained through telephone survey. Dietary intakes were assessed using 24-hour recalls. Following standard procedures, nutrient intakes were energy-adjusted and categorized into quintiles. Diet cost for each respondent was estimated using Seattle supermarket prices for 2004.

**Results:** Higher intakes of dietary fiber, potassium, calcium, and magnesium were associated with higher diet costs. The cost gradient was steepest for potassium. Higher intakes of saturated fats, trans fats and added sugar were associated with lower diet costs. Lower cost diets were more likely to be consumed by those with lower SES.

**Conclusion:** Nutrients commonly associated with a lower risk of chronic disease, contrast, nutrients associated with higher disease risk were associated with somewhat higher diet costs. Lower income groups had difficulty complying with dietary guidelines for chronic disease prevention.

**Citation:** Aggarwal A, Monsivais P, Drewnowski A (2012) Nutrient Intakes Linked to Better Health Outcomes Are Associated with Higher Diet Costs. *PLoS ONE* 7(5): e37533. doi:10.1371/journal.pone.0037533

Editor: Andrea S. Willey, Indiana University, United States of America

Attached prices to diet records in the year 2004

*J Am Diet Assoc.* 2009 May ; 109(5): 814–822. doi:10.1016/j.jada.2009.02.002.

## Lower-energy-density diets are associated with higher monetary costs per kilocalorie and are consumed by women of higher socioeconomic status

**FOOD POLICY**

By Pablo Monsivais, Anju Aggarwal, and Adam Drewnowski

### Following Federal Guidelines To Increase Nutrient Consumption May Lead To Higher Food Costs For Consumers

**Abstract** The federal *Dietary Guidelines for Americans, 2010*, emphasized the need for Americans to consume more potassium, dietary fiber, vitamin E, and calcium, and to get fewer calories from saturated fat and added sugar. We examined the economic impact of meeting these guidelines for adults in King County, Washington. We found that increasing consumption of potassium—the most expensive of the four recommended nutrients—would add \$380 per year to the average consumer's food costs. Meanwhile, each time consumers obtained 1 percent more of their daily calories from saturated fat and added sugar, their food costs significantly declined. These findings suggest that improving the American diet will require additional guidance for consumers, especially those with little budget flexibility, and new policies to increase the availability and reduce the cost of healthful foods.

## Study of French adults.

density (MJ/kg) using mean energy intakes. The study was examined for dietary

les and fruit.

energy intakes. The study was examined for dietary

DOI: 10.1377/hlthaff.2010.1273  
HEALTH AFFAIRS 30, NO. 8 (2011): –  
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**Anju Aggarwal** is project manager at the Center for Public Health Nutrition.

**Adam Drewnowski** is director of the Center for Public Health Nutrition and a professor of epidemiology at the School of Public Health, University of Washington.



# Diet cost and diet quality evidence from Spain and Japan

Int J Obes (Lond). 2006 Oct;30(10):1574-9. Epub 2006 Mar 21.

## High monetary costs of dietary patterns associated with lower body mass index: a population-based study.

Schröder H<sup>1</sup>, Marmugat J, Covas MI.

### Author information

#### Abstract

**INTRODUCTION:** Food choice is strongly influenced through economic constraints. The monetary costs for foods, especially those foods associated with a lower risk of obesity, have considerably increased during the last years. The purpose of this study was to determine the cost differences between low and high adherence to two dietary patterns which have been inversely associated with body mass index (BMI) and obesity.

**METHODS:** The subjects were Spanish men (n=1547) and women (n=1615) aged 25-74 years who were examined in 1999-2000, in a population-based cross-sectional survey in the northeast of Spain (Girona). Dietary intake was assessed using a food frequency questionnaire. Two dietary quality indices, namely the Mediterranean Diet Score (MDS) and the Healthy Eating Index (HEI), were created. Average food prices were calculated. Anthropometric variables were measured.

**RESULTS:** Adjusted linear regression analysis revealed that an increase in 1 Euro (1.25\$) of monetary diet cost was associated with a change of 0.46 units (P<0.001) and 2.03 units (P<0.001) in the MDS and HEI, respectively. The magnitude of the change in scores after standardization. Subjects who closely adhered to the MDS and HEI paid daily 1.2 Euro (1.50\$) (P<0.001) more for food consumption, respectively, than those who weakly adhered to these dietary patterns. Adjusted for several confounders showed an inverse association of the MDS (P=0.011) and the HEI (P<0.001) with BMI. BMI or =30) significantly decreased across quartile distribution of MDS (P=0.004) and HEI (P=0.001).

**CONCLUSION:** Data showed that a high adherence to the MDS and HEI, both inversely associated with BMI, were associated with higher diet costs as compared to a low adherence. This might be of importance for public health policies in an effort to develop diets preventing weight gain.

PMID: 16552405 DOI: 10.1038/sj.ijo.0803308

**Conclusion:** Nutrients commonly associated with a lower risk of chronic disease, contrast, nutrients associated with higher disease risk were associated with diets that somewhat explain why lower income groups fail to comply with dietary guidelines for chronic disease.

**Citation:** Aggarwal A, Monsivais P, Drewnowski A (2012) Nutrient Intakes Linked to Better Health Outcomes Are Associated with Higher Diet Costs. *PLOS ONE* 7(5): e37533. doi:10.1371/journal.pone.0037533

**Editor:** Andrea S. Willet, Indiana University, United States of America

Contents lists available at ScienceDirect

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Journal homepage: [www.elsevier.com/locate/ypmed](http://www.elsevier.com/locate/ypmed)



Linking diet costs with diet quality and BMI

and Healthy Eating Index (HEI) scores among 2007-2010

is<sup>c</sup>, Adam Drewnowski

Nutrition, University of Washington, Box 353410, Seattle, WA 98195, USA

Environ Health Insights, 2009 May 12;3:27-35.

## Monetary Diet Cost is Associated with not only Favorable but also Unfavorable Aspects of Diet in Pregnant Japanese Women: The Osaka Maternal and Child Health Study.

Murakami K<sup>1</sup>, Miyake Y, Sasaki S, Tanaka K, Ohya Y, Hirota Y; Osaka Maternal and Child Health Study Group.

### Author information

#### Abstract

While several observational studies in European countries have shown that higher monetary diet cost is associated with healthier diets, information on the relationship of cost to diet quality in other countries is sparse, including Japan. This cross-sectional study examined the association between monetary diet cost and dietary intake in a group of pregnant Japanese women. Subjects were 596 pregnant Japanese housewives. Dietary intake was estimated using a validated, self-administered, comprehensive diet history questionnaire. Monetary diet cost was calculated using retail food prices. Values of monetary diet cost and nutrient and food intake were energy-adjusted using the density method. Monetary diet cost was associated positively with the intake of protein, total fat, saturated fatty acids, dietary fiber, cholesterol, sodium, potassium, calcium, magnesium, iron, vitamins A, D, E, C, and folate, and inversely with that of carbohydrate. For foods, cost was associated positively with the intake of potatoes, pulses and nuts, fish and shellfish, meat, dairy products, vegetables, and fruits, and inversely with that of rice and bread. No association was seen for noodles, confectioneries and sugars, fats and oils, or eggs. Cost was also associated inversely with dietary energy density. In conclusion, monetary diet cost was associated with not only favorable aspects of diet, including a higher intake of dietary fiber, key vitamins and minerals, fruits, and vegetables and lower dietary energy density, but also unfavorable aspects, including a higher intake of fat and sodium and lower intake of carbohydrate and rice, in a group of pregnant Japanese women.

**KEYWORDS:** Japan; diet cost; food intake; nutrient intake; pregnant women

PMID: 20508755 PMCID: PMC2872571

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improving  
consumers, esp  
to increase the



# Evidence from Nurses Health Study

*Int J Obes (Lond)*. 2006 Oct;30(10):1574-9. Epub 2006 Mar 21.

## High monetary costs of dietary patterns associated with obesity: a population-based study.

OPEN  Schröder H<sup>1</sup>, Mamugat J, Covas MI.

### Author information

Nutrition Abstract

**INTRODUCTION:** Food choice is strongly influenced through economic factors. Individuals with a lower risk of obesity, have considerably increased their energy intake. Low income individuals are at a higher risk of obesity.

**METHODS:** The subjects were Spanish men (n=1547) and women (n=1547) from a population-based study in the north of Spain. Dietary quality indices, namely the Mediterranean Diet Score (MDS) and the Alternative Healthy Eating Index (AHEI) were measured.

**RESULTS:** Adjusted linear regression analysis revealed that an increase of 0.46 units (P<0.001) and 2.03 units (P<0.001) in the MDS and AHEI scores after standardization. Subjects who closely adhered to the MDS (P<0.001) more for food consumption, respectively, than those who did not.

**CONCLUSION:** Data showed that a high adherence to the MDS and AHEI as compared to a low adherence. This might be of important for preventing weight gain.

PMID: 16552405 DOI: 10.1038/sj.ijo.0803308

**Conclusion:** Nutrients commonly associated with a lower risk of chronic disease, nutrients associated with higher disease risk were associated with a lower risk of obesity. This might explain why lower income groups fail to comply with diet recommendations.

**Citation:** Agganwal A, Monsivais P, Drewnowski A (2012) Nutrient Intakes Linked to Better Health Outcomes. *PloS ONE* 7(5): e37533. doi:10.1371/journal.pone.0037533

**Editor:** Andrea S. Willet, Indiana University, United States of America

## Relation of food cost to healthfulness of diet among US women<sup>1-4</sup>

Adam M Bernstein, David E Bloom, Bernard A Rosner, Mary Franz, and Walter C Willett

### ABSTRACT

**Background:** Few studies have evaluated the cost of a diet that may prevent cardiovascular disease. High scores on the Alternative Healthy Eating Index (AHEI) have been associated with lower rates of cardiovascular disease.

**Objective:** We sought to evaluate the cost of a dietary pattern that may prevent cardiovascular disease among women residing in the United States.

**Design:** Using food-cost data from the US Department of Agriculture, we explored relations between spending on food and AHEI scores among 78,191 participants in the Nurses' Health Study. By using linear regression, we estimated the change in AHEI score (range: 2.5–87.5) for a \$1 increase in spending on various food groups. **Results:** Study participants in the highest energy-adjusted spending quintile spent 124% as much money each day as those in the lowest quintile. The difference in AHEI scores (10th–90th percentile) between all study participants was 30 index points (Spearman's correlation coefficient between total spending and AHEI = 0.44). The difference in AHEI scores (10th–90th percentile) within each quintile of spending ranged from 25 to 29 index points. Greater spending on nuts, soy and beans, and whole grains was associated with a higher AHEI score. Greater spending on red and processed meats and high-fat dairy was associated with a lower AHEI score.

**Conclusions:** Although spending more money was associated with a healthier diet, large improvements in diet may be achieved without increased spending. The purchase of plant-based foods may offer the best investment for dietary health. *Am J Clin Nutr* 2010;92:1197–203.

dietary index score among study participants in the Nurses' Health Study.

### SUBJECTS AND METHODS

#### Study population and Nurses' Health Study questionnaire

The details of the study population have been described in detail (18–22). In brief, the Nurses' Health Study began in 1976 when 121,700 female registered nurses aged 30–55 y and residing in 11 US states provided detailed information on their medical history and lifestyle. Every 2 y, follow-up questionnaires have been sent out to update information on potential risk factors and to identify newly diagnosed cases of CVD (defined as coronary artery disease plus stroke), cancers, and other diseases. In 1980, a 61-item food-frequency questionnaire (FFQ) was included to assess intake of specific foods. In 1984, the FFQ was expanded to include 116 food items. Similar questionnaires were used to update dietary intake in 1986, 1990, 1994, 1998, 2002, and 2006.

Demographic data were queried on different questionnaires; in 1992, study participants reported their highest level of education (registered nurse, bachelor's, master's, or doctorate); in 2000, they reported their marital status (single, widowed, divorced, separated, or never married), living situation (alone, with spouse, with other family, in a nursing home, or other living situation), and current employment situation (retired, full- or part-time nursing, full- or part-time non-nursing). Place of residence is reported during each questionnaire cycle. Race was most recently queried in 2004 (Spanish/Hispanic/Latina, white, African American or

The American Journal of Clinical Nutrition

# Evidence from US National level Surveys

European Journal of Clinical Nutrition (2006) 60, 434–438  
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## Nutrient Intakes Linked to Better Health Outcomes Associated with Higher Diet Costs

Anju Aggarwal<sup>1,2\*</sup>, Pablo Monsivais<sup>1,3</sup>, Adam Drewnowski<sup>1</sup>

<sup>1</sup>Center for Public Health Nutrition, School of Public Health, University of Washington, Seattle, WA, USA; <sup>2</sup>Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA; <sup>3</sup>Collaboration Centre for Diet and Activity Research, Cambridge Institute of Public Health, Cambridge, UK

### Abstract

**Purpose:** Degrees of nutrient intake and food groups have been associated with health outcomes. Higher intakes of specific nutrients may also be associated with differential diet costs (SES). The present study examined degrees of nutrient intake, food group intake, and diet costs by SES.

**Methods:** Socio-demographic data for a stratified random sample of US adults were obtained through telephone survey. Dietary intakes were assessed using standard procedures, nutrient intakes were energy-adjusted, and diet costs were estimated using Seattle Food Cost Survey.

**Results:** Higher intakes of dietary fiber, vitamins A, C, D, E, and magnesium were associated with higher diet costs. The cost gradient was similar for higher intakes of saturated fats, trans fats, and potassium. Lower cost lower quality diets were more likely to be consumed by lower income groups.

**Conclusion:** Nutrients commonly associated with a lower risk of chronic disease, contrast, nutrients associated with higher diet costs. We hypothesize that these findings somewhat explain why lower income groups are more likely to consume diets with higher risk of chronic disease.

**Citation:** Aggarwal A, Monsivais P, Drewnowski A (2012) Nutrient Intakes Linked to Better Health Outcomes Associated with Higher Diet Costs. *PLoS ONE* 7(5): e37533. doi:10.1371/journal.pone.0037533

**Editor:** Andrea S. Willet, Indiana University, United States of America



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journal homepage: [www.elsevier.com/locate/ypmed](http://www.elsevier.com/locate/ypmed)



## Relation between diet cost and Healthy Eating Index 2010 scores among adults in the United States 2007–2010



Colin D. Rehm<sup>a,b,\*</sup>, Pablo Monsivais<sup>c</sup>, Adam Drewnowski<sup>a</sup>

<sup>a</sup> Department of Epidemiology and Center for Public Health Nutrition, University of Washington, Box 353410, Seattle, WA 98195, USA

<sup>b</sup> Friedman School of Nutrition Science & Policy, Tufts University, 150 Harrison Ave, Room 247, Boston, MA 02111, USA

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### ARTICLE INFO

Available online 24 January 2015

### Keywords:

Diet/economics  
Diet quality  
Nutrition surveys  
Cross-sectional studies  
Nutrition policy  
Dietary guidelines

### ABSTRACT

**Background.** Food prices may be one reason for the growing socioeconomic disparities in diet quality.

**Objective.** To evaluate the association between diet costs and the Healthy Eating Index-2010 (HEI-2010).

**Methods.** Cross-sectional study based on 11,181 adults from the 2007–2010 National Health and Nutrition Examination Survey, analyzed in spring 2014. Diet cost was estimated by linking dietary data with a national food price database. The HEI-2010, a measure of adherence to the dietary guidelines, was the outcome. The population ratio method was used to estimate the average HEI-2010 scores by quintile of energy-adjusted diet costs. Additional analyses evaluated the association between cost and HEI-2010 components.

**Results.** There was a strong positive association between lower energy-adjusted diet costs and lower HEI-2010 scores. The association was stronger among women ( $p$ -interaction = 0.003). Lower diet costs were associated with lower consumption of vegetables, fruits, whole grains, and seafood, and higher consumption of refined grains and solid fat, alcohol and added sugars.

**Conclusions.** Lower energy-adjusted diet costs were associated with lower-quality diets. Future efforts to improve the nutritional status of the US public should take food prices and diet costs into account.

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National prices attached to NHANES



# Recent evidence from Mexico dietary data

European Journal of Clinical Nutrition  
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## Nutrient Intakes Linked Associated with Higher

Anju Aggarwal<sup>1,2\*</sup>, Pablo Monsivais<sup>1,3</sup>, Ad

<sup>1</sup>Center for Public Health Nutrition, School of Public Health, Unive  
Department of International Health, Johns Hopkins Bloomberg Schoo  
Collaboration Centre for Diet and Activity Research, Cambridge Inst

### Abstract

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**Methods:** Socio-demographic data for a stratified  
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potassium, and magnesium. Higher intakes of sa  
costs. Lower cost lower quality diets were more

**Conclusion:** Nutrients commonly associated with  
contrast, nutrients associated with higher diseas  
somewhat explain why lower income groups fail  
chronic disease.

**Citation:** Aggarwal A, Monsivais P, Drewnowski A (2012) Nutrient  
ONE 7(5): e37533. doi:10.1371/journal.pone.0037533

**Editor:** Andrea S. Willet, Indiana University, United States of Am

J Epidemiol Community Health. 2017 Apr 6. pii: jech-2016-207781. doi: 10.1136/jech-2016-207781. [Epub ahead of print]

## Energy density of foods and diets in Mexico and their monetary cost by socioeconomic strata: analyses of ENSANUT data 2012.

Mendoza A<sup>1,2</sup>, Pérez AE<sup>2</sup>, Aggarwal A<sup>1</sup>, Drewnowski A<sup>1</sup>.

Author information

### Abstract

**BACKGROUND:** In January 2014, Mexico implemented an 8% tax on non-essential foods with energy density  $\geq 275$  kcal/100 g, with a view to prevent obesity. This study explored energy density of foods and diets in Mexico and their monetary cost across population subgroups.

**METHODS:** Dietary intakes for 3057 adults (ages  $\geq 19$  years) were obtained from the nationally representative Encuesta Nacional de Salud y Nutrición (ENSANUT 2012). Energy density (kcal/g) was calculated for foods, food groups and total diets. The mean national retail prices for 153 foods were obtained from the National Institute for Geography and Statistics (INEGI). The monetary cost of total diets (MXN/day) was estimated by attaching food prices to dietary intakes from the ENSANUT food frequency questionnaire. A series of descriptive analyses and regression models examined associations among dietary energy density and diet cost by age, gender, rural or urban residence and socioeconomic status (SES).

**RESULTS:** Energy-dense grains, fats and sweets cost less per calorie than did milk and dairy, meat, vegetables and fruit. Lower cost diets derived more calories from tortillas, tamales, beans and sugar, whereas higher cost diets contained more non-essential energy-dense processed foods and more sugar sweetened beverages, and fruits and vegetables. At each quintile of energy intake, higher dietary energy density was associated with lower energy-adjusted diet costs. Traditional energy-dense tortillas and tamales, also characterised by lower cost, were consumed more by the rural poor. Urban dwellers had more 'western-style' diets.

**CONCLUSIONS:** Food patterns in Mexico appear to be driven by monetary cost and SES.

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**KEYWORDS:** DIET; EPIDEMIOLOGY; Economic evaluation; Health inequalities; NUTRITION

## National prices attached to ENSANUT 2012

# Recent article from Lancet

## Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study

Victoria Miller, Salim Yusuf, Clara K Chow, Mahshid Dehghan, Daniel J Corsi, Karen Lock, Barry Popkin, Sumathy Rangarajan, Rasha Khatib, Scott A Lear, Prem Mory, Manmeet Kaur, Viswanathan Mohan, Krishnapillai Vijayakumar, Rajeev Gupta, Annamarie Kruger, Lungiswa Tsolekile, Noushin Mohammadifard, Omar Rahman, Annika Rosengren, Alvaro Avezum, Andrés Orlandini, Noorhassim Ismail, Patricio Lopez-Jaramillo, Afzalhussein Yusufali, Kubilay Karsidag, Romaina Iqbal, Jephth Chifamba, Solange Martinez Oakley, Farnaza Ariffin, Katarzyna Zatonska, Paul Poirier, Li Wei, Bo Jian, Chen Hui, Liu Xu, Bai Xiulin, Koon Teo, Andrew Mentz

### Summary

**Background** Several international guidelines recommend the consumption of two servings of fruits and three servings of vegetables per day, but their intake is thought to be low worldwide. We aimed to determine the extent to which such low intake is related to availability and affordability.

**Methods** We assessed fruit and vegetable consumption using data from country-specific, validated semi-quantitative food frequency questionnaires in the Prospective Urban Rural Epidemiology (PURE) study, which enrolled participants from communities in 18 countries between Jan 1, 2003, and Dec 31, 2013. We documented household income data from participants in these communities; we also recorded the diversity and non-sale prices of fruits and vegetables from grocery stores and market places between Jan 1, 2009, and Dec 31, 2013. We determined the cost of fruits and vegetables relative to income per household member. Linear random effects models, adjusting for the clustering of households within communities, were used to assess mean fruit and vegetable intake by their relative cost.

**Findings** Of 143 305 participants who reported plausible energy intake in the food frequency questionnaire, mean fruit and vegetable intake was 3·76 servings (95% CI 3·66–3·86) per day. Mean daily consumption was 2·14 servings (1·93–2·36) in low-income countries (LICs), 3·17 servings (2·99–3·35) in lower-middle-income countries (LMICs), 4·31 servings (4·09–4·53) in upper-middle-income countries (UMICs), and 5·42 servings (5·13–5·71) in high-income countries (HICs). In 130 402 participants who had household income data available, the cost of two servings of fruits and three servings of vegetables per day per individual accounted for 51·97% (95% CI 46·06–57·88) of household income in LICs, 18·10% (14·53–21·68) in LMICs, 15·87% (11·51–20·23) in UMICs, and 1·85% (–3·90 to 7·59) in HICs ( $p_{trend}=0·0001$ ). In all regions, a higher percentage of income to meet the guidelines was required in rural areas than in urban areas ( $p<0·0001$  for each pairwise comparison). Fruit and vegetable consumption among individuals decreased as the relative cost increased ( $p_{trend}=0·00040$ ).

**Interpretation** The consumption of fruit and vegetables is low worldwide, particularly in LICs, and this is associated

[Epub ahead of print]

monetary cost by socioeconomic strata:

## Local prices attached to FFQ

all foods with energy density  $\geq 275$  kcal/100 g, with a view to their monetary cost across population subgroups. We used nationally representative Encuesta Nacional de Salud y Demografía (ENSA) data to estimate the mean energy density of food groups and total diets. The mean national retail prices for 153 food items were used to estimate the monetary cost of total diets (MXN/day) was estimated from a series of descriptive analyses and regression analyses by gender, rural or urban residence and socioeconomic status.

and dairy, meat, vegetables and fruit. Lower cost diets derived from the ENSA data contained more non-essential energy-dense processed foods. Higher energy intake, higher dietary energy density was associated with higher monetary cost. Diets also characterised by lower cost, were consumed more by

and SES.

already granted under a licence) please go to

ITION

OPEN ACCESS

Nutrition  
Associations

Anju Aggarwal

1Center for Public Health  
Department of International  
Collaboration Centre for

### Abstract

**Purpose:** Degree of specific nutrients (SES). The prevalence of SES.

**Methods:** Socioeconomic status obtained through following standard quintiles. Diet

**Results:** High magnesium and potassium, and lower costs. Lower

**Conclusion:** In contrast, nutrients somewhat associated with chronic disease

Citation: Aggarwal  
ONE 7(5): e37533. doi:

Editor: Andrea S. V



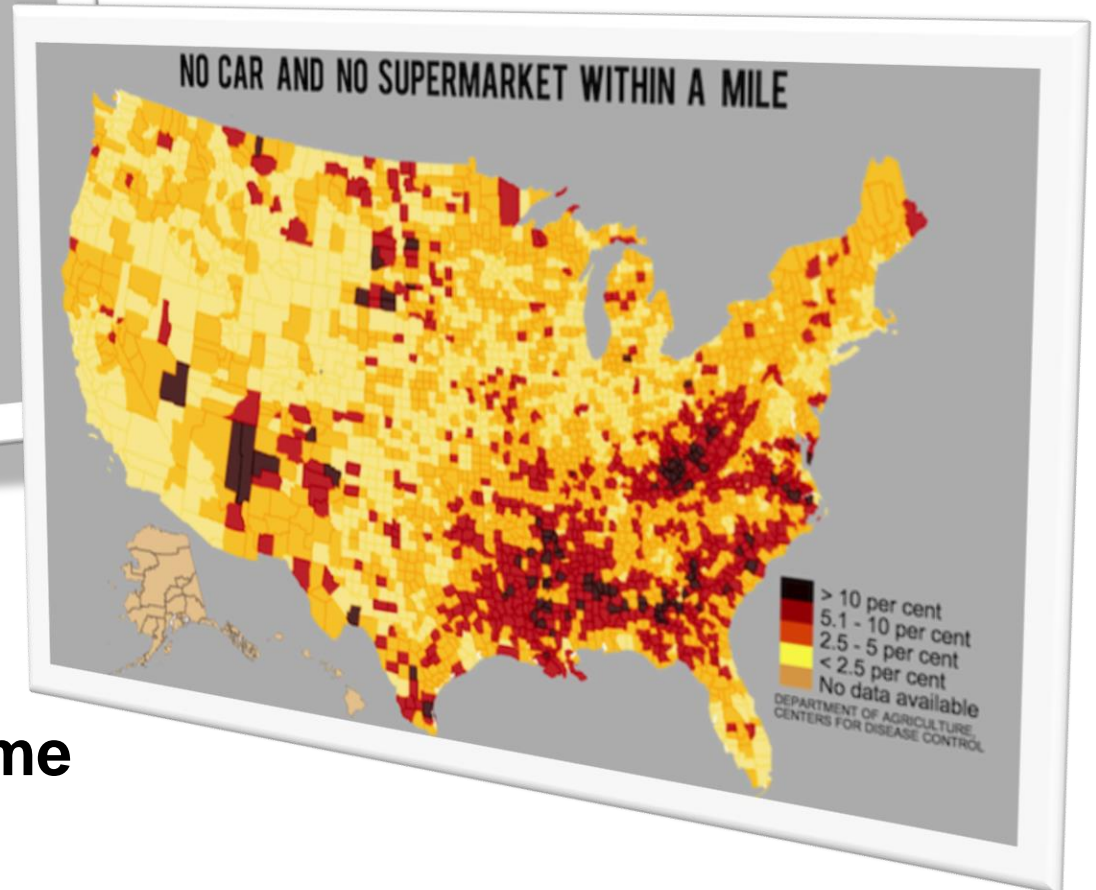
# Geographic dimension of food access

Are healthy foods available and physically accessible to the consumer?

## WHAT IS A 'FOOD DESERT'?

URBAN NEIGHBOURHOODS & RURAL TOWNS WITHOUT READY ACCESS TO FRESH, HEALTHY & AFFORDABLE FOOD.

Instead of supermarkets and grocery stores, these communities may have no food access or are served only by fast food restaurants and convenience stores that offer few healthy, affordable food options. In the United States, 5.8 million households live at least half a mile (about .8 km) from a supermarket and are without access to a vehicle. Of those homes, 2.5 million are within low-income areas.



Supermarket within 1 mile from home

Neighborhood-centric approach

# Geographic dimension of food access

Are healthy foods available and physically accessible to the consumer?

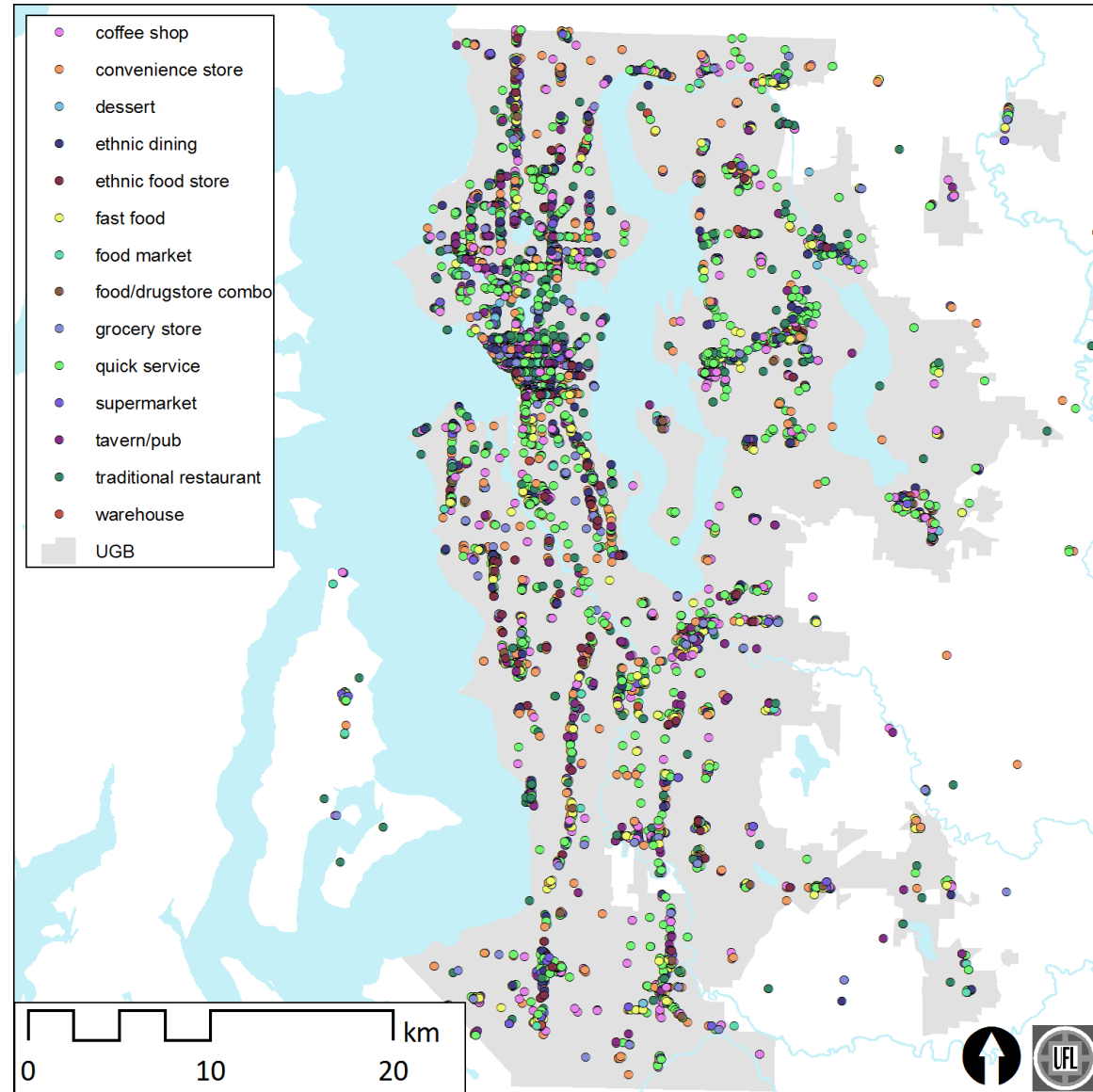
Moved to person-centric approach

**Check out this video!**

<https://vimeo.com/67365274>

# Moved out of neighborhood boundaries to define food environment

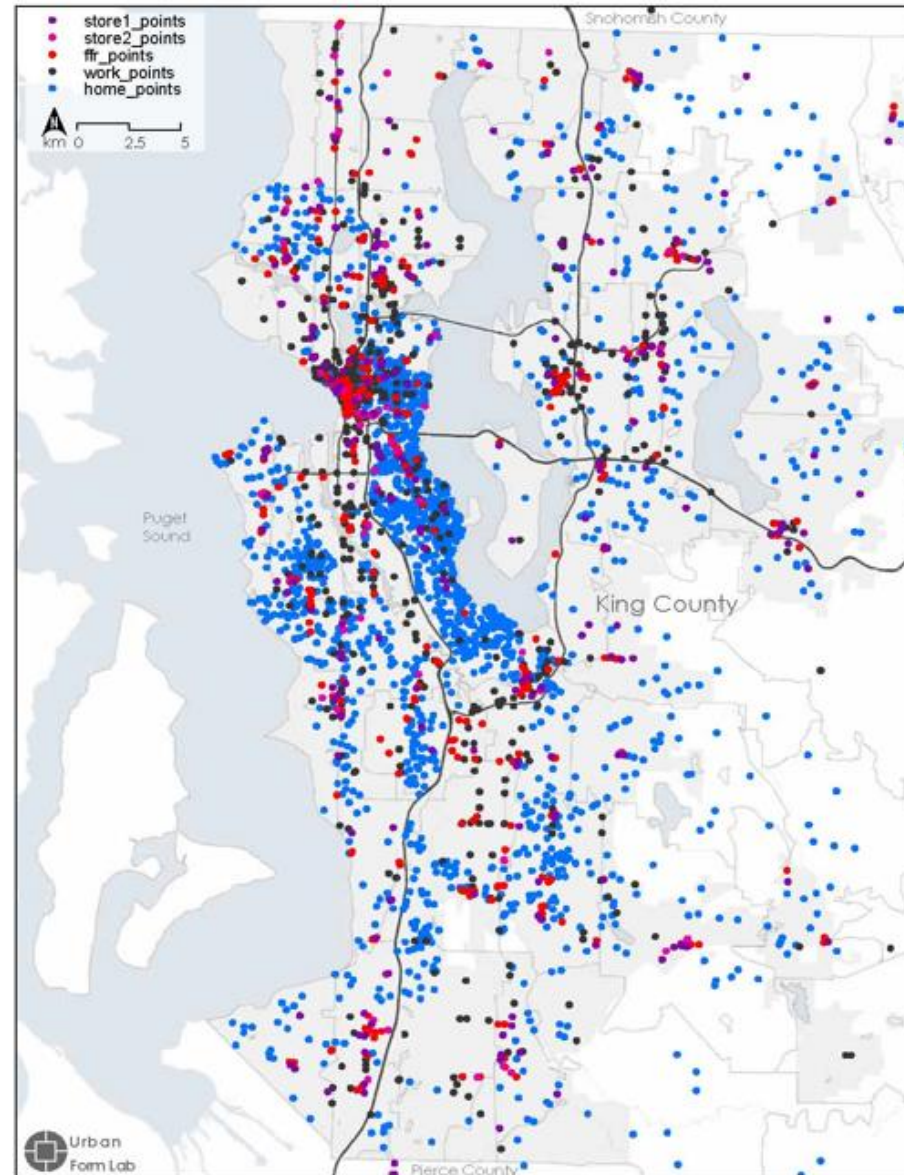
## Geolocated food sources



Source: SOS I. Developed by UFL.

# Moved out of neighborhood boundaries to define food environment

Geolocated places of food purchase and consumption

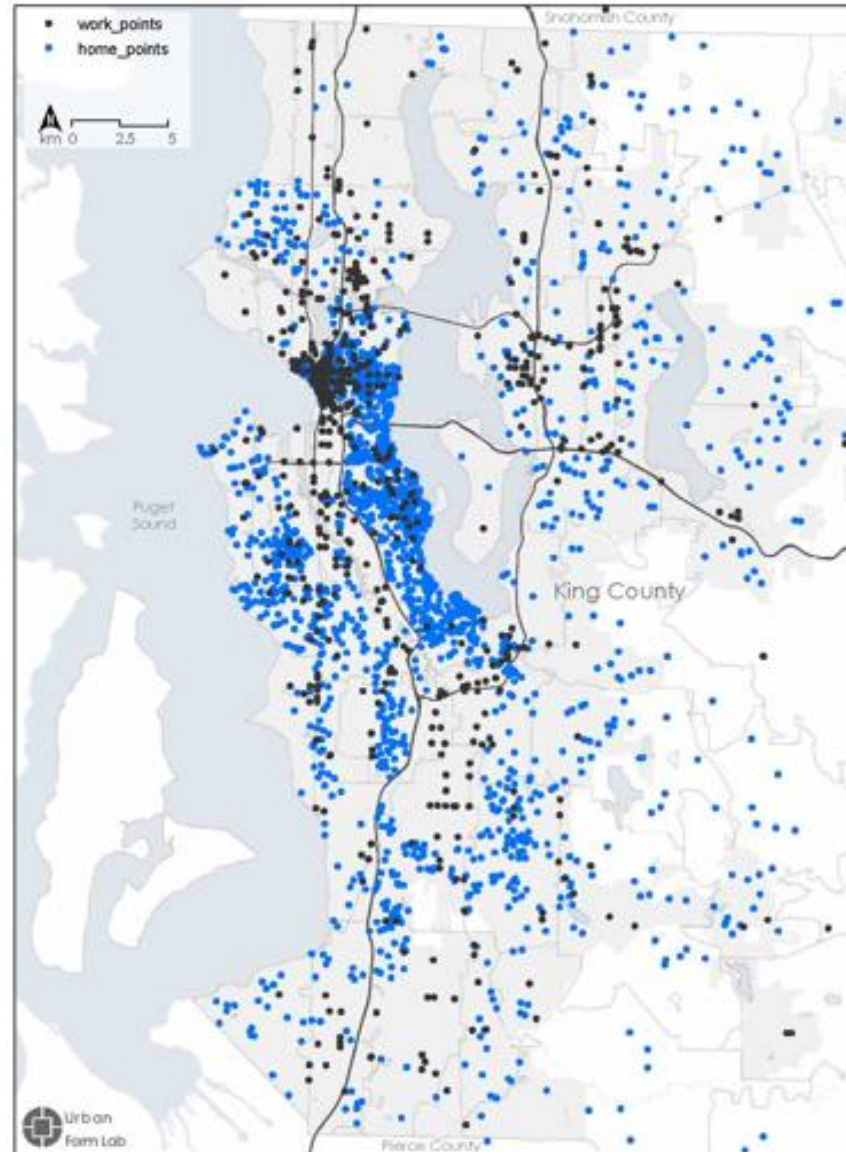


Source: SOS I. Developed by UFL

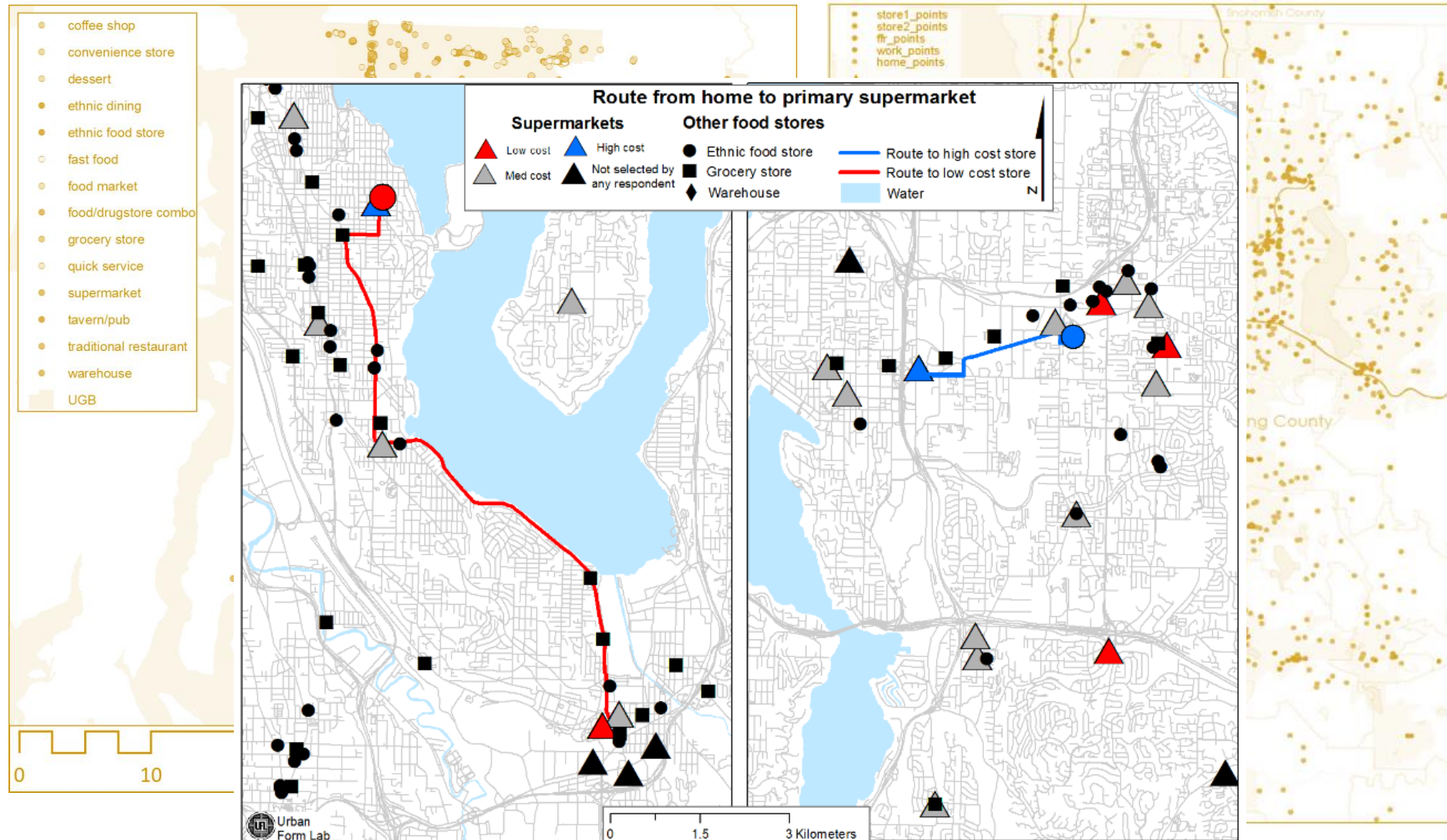


# Moved out of neighborhood boundaries to define food environment

Geolocated  
respondent's  
home/ work/  
primary activity



# Connected the two!



Source: Aggarwal et al, Am J Pub Health 2014. <https://www.ncbi.nlm.nih.gov/pubmed/24625173>

# Opens the door to consumer-centric metrics of geographic access

Home

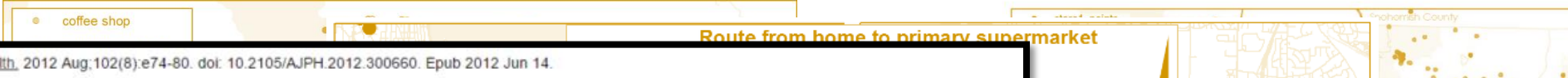
- Distance to primary food stores
- Distance to fast-food restaurants
- Distance to restaurants
- Distance to convenience stores

Work/  
primary  
activity

- Distance to primary food stores
- Distance to fast-food restaurants
- Distance to restaurants
- Distance to convenience stores



# Physical distance to food shopping destinations not linked to diets or obesity in King County



coffee shop

Route from home to primary supermarket

King County

Am J Public Health. 2012 Aug;102(8):e74-80. doi: 10.2105/AJPH.2012.300660. Epub 2012 Jun 14.

## Obesity and supermarket access: proximity or price?

Drewnowski A<sup>1</sup>, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV.

Author information

**Abstract**

**OBJECTIVES:** We examined whether physical proximity to supermarkets or supermarket price was a risk factor for obesity.

**METHODS:** The Seattle Obesity Study (SOS) collected and geocoded data on home addresses of a representative sample of adult residents of King County, Washington. Supermarkets were stratified into low, medium, and high cost according to the market basket. Sociodemographic and health data were obtained from a telephone survey. We tested the associations between obesity and supermarket variables.

**RESULTS:** Only 1 in 7 respondents reported shopping at the nearest supermarket. The risk of obesity was not associated with physical distance to the nearest supermarket or the supermarket that SOS participants shopped at most frequently. Supermarket choice, by price, was found to be inversely and significantly associated with obesity risk. Higher level sociodemographic and lifestyle variables, and proximity measures (adjusted relative risk=0.3) were also associated with obesity risk.

**CONCLUSIONS:** Improving physical access to supermarkets may be one strategy to deal with the problem of obesity. Improving access to healthy foods is another.

Am J Public Health. 2014 May; 104(5): 917-923.  
Published online 2014 May. doi: 10.2105/AJPH.2013.301763

PMCID: PMC3987578  
NIHMSID: NIHMS592176

## Access to Supermarkets and Fruit and Vegetable Consumption

Anju Aggarwal, PhD,<sup>1</sup> Andrea J. Cook, PhD,<sup>2</sup> Junfeng Jiao, PhD,<sup>3</sup> Rebecca A. Sequin, PhD,<sup>4</sup> Anne Vernez Moudon, DrSc,<sup>5</sup> Philip M. Hurvitz, PhD,<sup>6</sup> and Adam Drewnowski, PhD<sup>1</sup>

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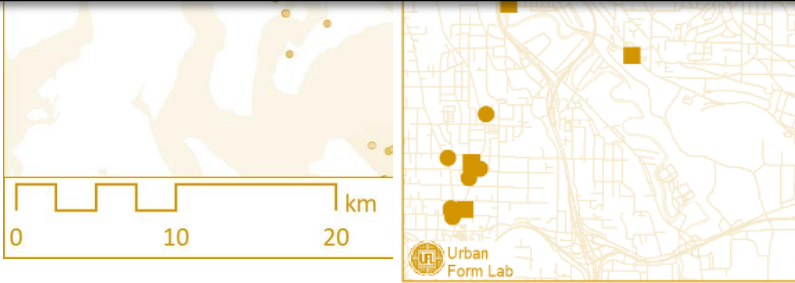
**Abstract** Go to:

**Objectives.** We examined whether supermarket choice, conceptualized as a proxy for underlying personal factors, would better predict access to supermarkets and fruit and vegetable consumption than mere physical proximity.

**Methods.** The Seattle Obesity Study geocoded respondents' home addresses and locations of their primary supermarkets. Primary supermarkets were stratified into low, medium, and high cost according to the market basket cost of 100 foods. Data on fruit and vegetable consumption were obtained during telephone surveys. Linear regressions examined associations between physical proximity to primary supermarkets, supermarket choice, and fruit and vegetable consumption. Descriptive analyses examined whether supermarket choice outweighed physical proximity among lower-income and vulnerable groups.

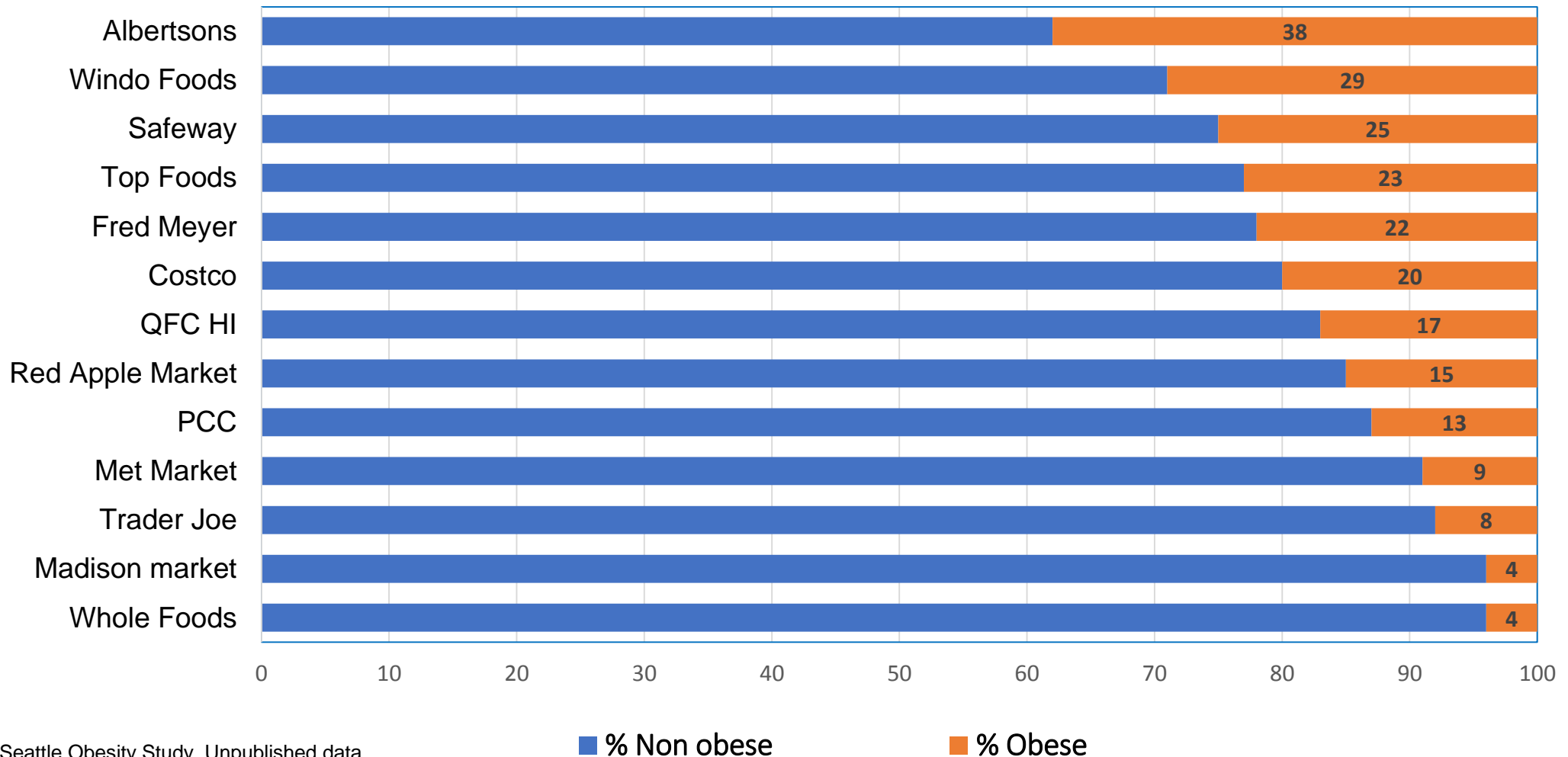
**Results.** Only one third of the respondents shopped at their nearest supermarket for their primary food supply. Those who shopped at low-cost supermarkets were more likely to travel beyond their nearest supermarket. Fruit and vegetable consumption was not associated with physical distance but, with supermarket choice, after adjusting for covariates.

**Conclusions.** Mere physical distance may not be the most salient variable to reflect access to supermarkets.



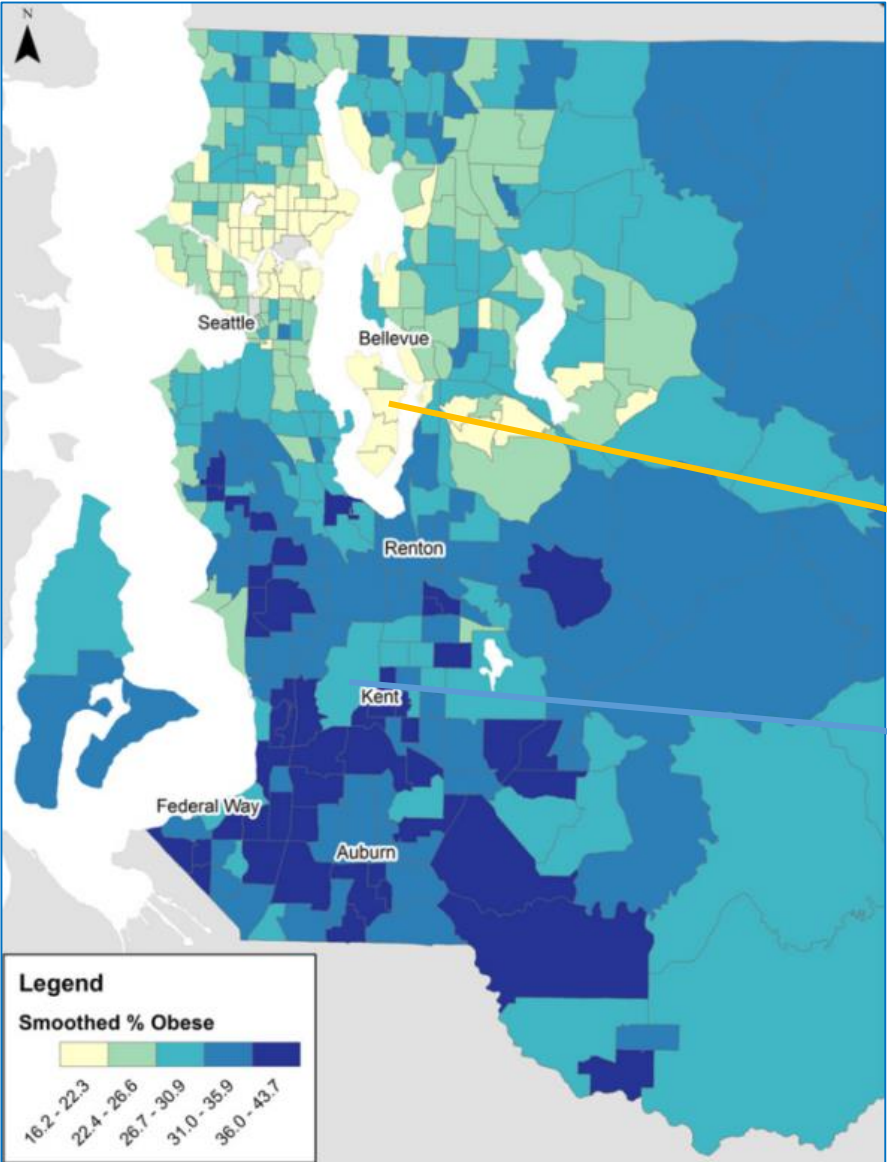
Urban Form Lab

# Geographic access not a barrier in King County, huge disparities in obesity prevalence still exist



Source: Seattle Obesity Study. Unpublished data

# Introduced a spatial dimension to nutrition epidemiology



## Geographic distribution of obesity at census tract level

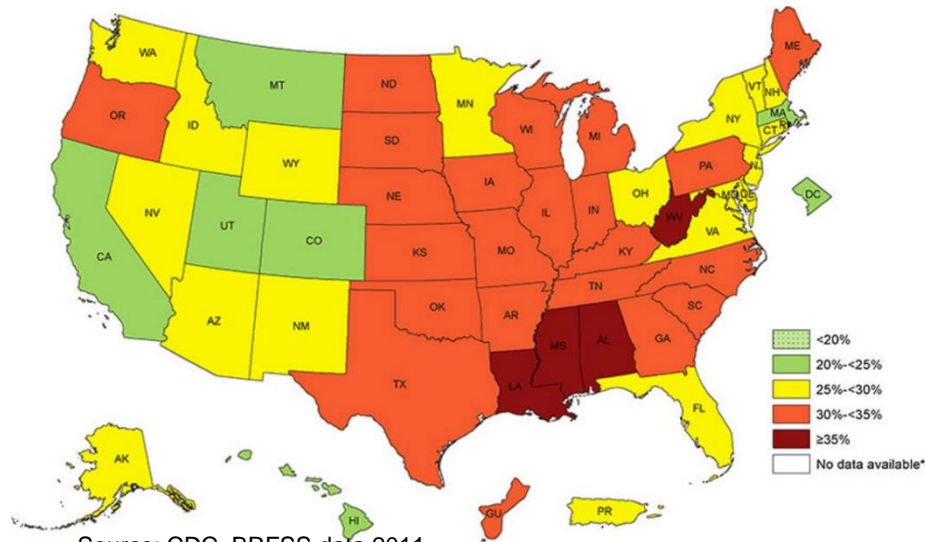
Obesity prevalence  
16-22%

Obesity prevalence  
36-43%

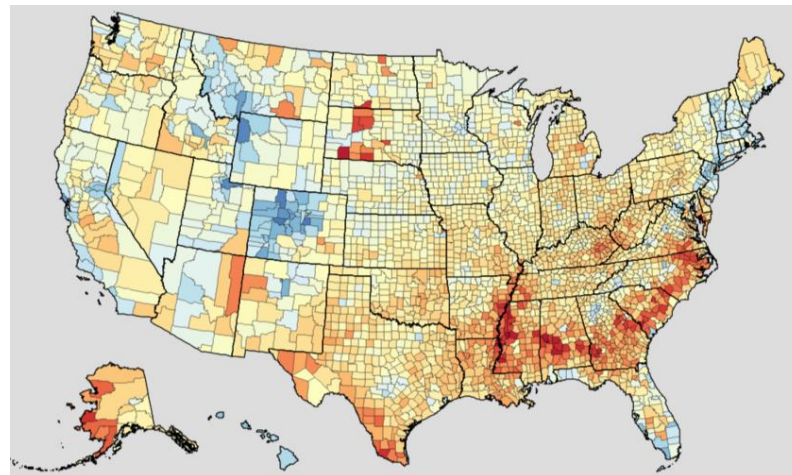
Source: Drewnowski et al, Int J Obes 2014.  
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3955743/>



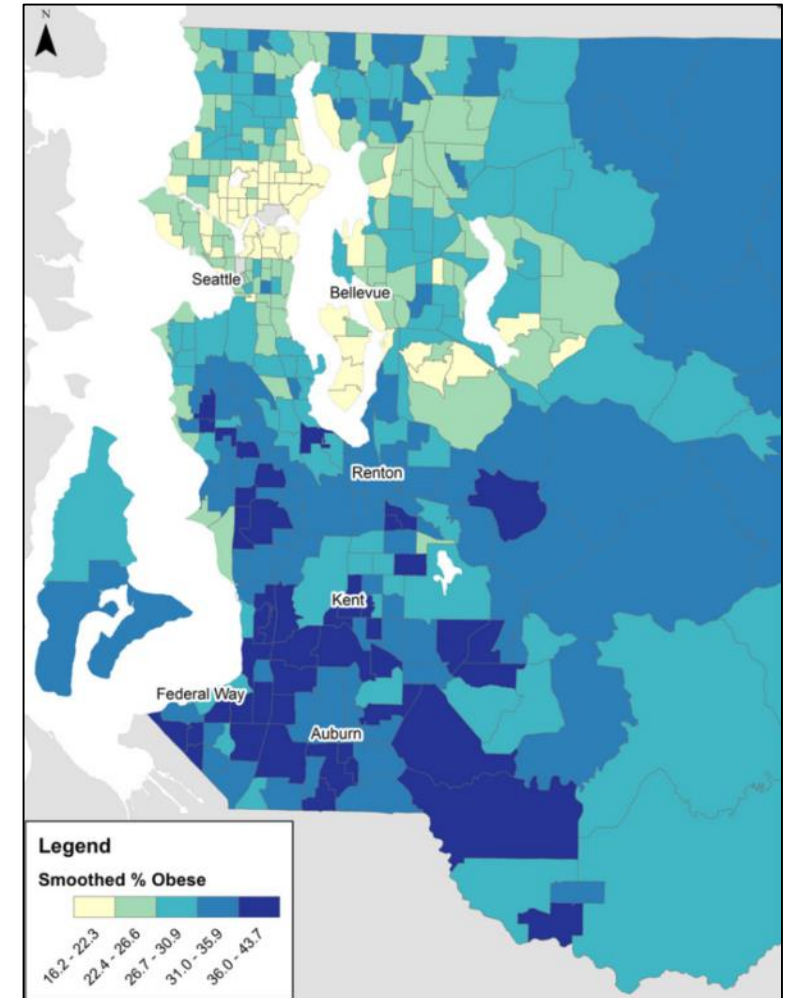
# Moving from State/ County level indicators down to census to neighborhood level



Source: CDC, BRFSS data 2011  
<https://www.cdc.gov/obesity/data/prevalence-maps.html>

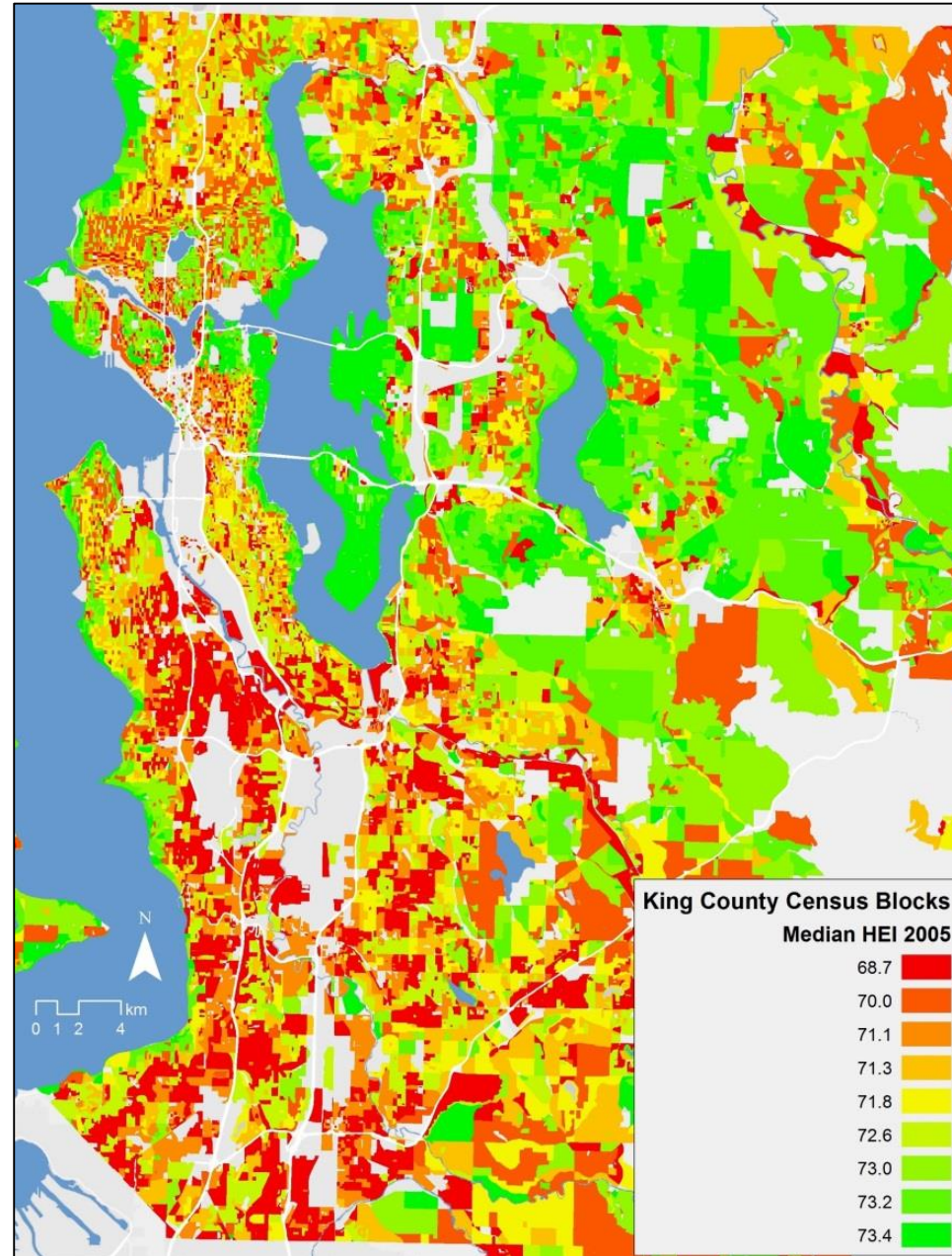


Source: Obesity prevalence, females, age-standardized, 2011 IHME  
<http://vizhub.healthdata.org/subnational/usa>



Source: Drewnowski et al, Int J Obes 2014.  
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3955743/>

# Geographic distribution of diet quality by census blocks - 1<sup>st</sup> time ever!



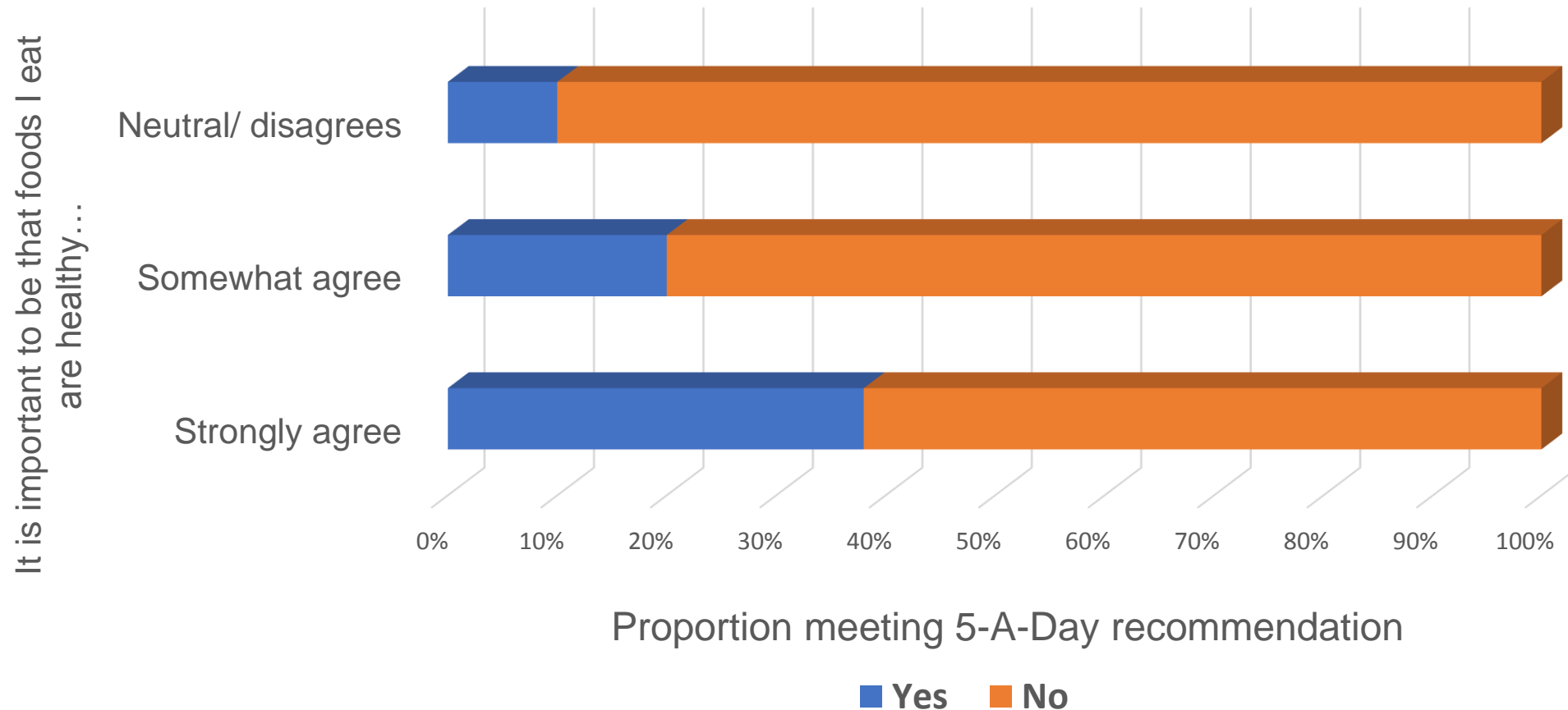
# Psychosocial dimension of food access

- Positive attitude towards eating healthy/ inexpensive/ convenient (5- point Likert scale)
- Cooking-at-home frequency per week
- Time spent cooking and cleaning after meals per day

Using standard previously validated questions from national level surveys

# Psychosocial dimension of food access

Positive attitude towards healthy foods was associated with much higher intakes of fruits and vegetables





# Positive attitude towards healthy foods associated with higher quality diets irrespective of where you shop!

## RESEARCH

### Research and Professional Briefs

## Positive Attitude toward Healthy Eating Associated with Higher Diet Quality at All Cost Levels in Supermarkets

Anju Aggarwal, PhD; Pablo Monsivais, PhD; Andrea J. Cook, PhD; Adam D. Drewnowski, PhD

#### ARTICLE INFORMATION

##### Article history:

Accepted 5 June 2013  
Available online 2 August 2013

##### Keywords:

Attitude toward healthy eating  
Supermarket access and food environment  
Cost level of supermarkets  
Diet quality  
Fruit and vegetable intake

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2212-2672 Open access under CC BY license.  
<http://dx.doi.org/10.1016/j.jand.2013.06.006>

#### ABSTRACT

Shopping at low-cost supermarkets examined whether a gradient in diet quality among supermarket patrons. Data on socioeconomic status, supermarket choice were collected from adult residents of King County, Washington. Thirteen supermarkets were categorized as low-, medium-, and high cost, based on quality measures were energy density and total servings of fruits and vegetables. The analysis was adjusted for age, sex, education, attitudes, and SES. Shopping at low-cost supermarkets was associated with higher quality diets. These associations remained after taking attitudinal measures into account. Attitudes toward healthy eating were associated with higher quality diets in low-, medium-, or high-cost supermarkets. These findings imply that promoting nutrition education for supermarket patrons from having higher quality diets. Promoting nutrition education for those catering to low-income populations.

J Acad Nutr Diet. 2014;114:266-274.

**Table 3.** Adjusted<sup>a</sup> mean±standard error of diet-quality measures by attitude toward healthy eating, before and after stratifying by supermarket type

Independent variables	n	Energy density (kcal/g)	MAR <sup>b</sup> (% adequacy/day)	Total servings of fruits + vegetables/day
<i>mean±standard error<sup>c</sup></i>				
<b>Attitude toward healthy eating</b>				
Neutral or negative	49	1.31±0.06*	67±1.78***	2.55±0.39**
Somewhat positive	329	1.17±0.02*	73±0.99***	3.68±0.24**
Strongly positive	585	1.11±0.02**	76±0.95***	4.80±0.23***
<b>After stratifying by supermarket type</b>				
<b>Among low-cost supermarket patrons</b>				
Attitude toward healthy eating				
Neutral or negative	16	1.21±0.07	68±3.25*	2.83±0.47***
Somewhat positive	122	1.15±0.04	74±1.69*	4.08±0.37***
Strongly positive	168	1.08±0.04*	77±1.67*	5.27±0.44***
<b>Among medium-cost supermarket patrons</b>				
Attitude toward healthy eating				
Neutral or negative	33	1.34±0.08*	67±2.14*	2.46±0.54*
Somewhat positive	191	1.18±0.04*	72±1.33*	3.53±0.37*
Strongly positive	321	1.11±0.03*	76±1.25***	4.55±0.32***
<b>Among high-cost supermarket patrons</b>				
Attitude toward healthy eating				
Neutral or negative	0	—	—	—
Somewhat positive	16	1.21±0.13	79±3.86	3.33±0.89***
Strongly positive	96	1.11±0.09	82±3.22	5.21±0.80***

THE SELECTION OF HIGH-QUALITY DIETS IS influenced by knowledge, attitudes, and the economic

whether there exists a gradient in diet quality among supermarket shoppers, and the extent to which the variability



# Frequent cooking-at-home associated with better compliance with dietary guidelines at no extra cost

Am J Prev Med. 2017 May;52(5):616-624. doi: 10.1016/j.amepre.2017.01.017. Epub 2017 Feb 28.

## Cooking at Home: A Strategy to Comply With U.S. Dietary Guidelines at No Extra Cost.

Tiwari A<sup>1</sup>, Aggarwal A<sup>2</sup>, Tang W<sup>2</sup>, Drewnowski A<sup>3</sup>

HEI-2010

Frequency of cooking dinner at home				
Low	Ref		Ref	
Medium	<b>4.63 (1.68, 7.58)</b>	<b>0.002</b>	<b>4.55 (1.58, 7.51)</b>	<b>0.003</b>
High	<b>7.68 (4.93, 10.42)</b>	<b>0.001</b>	<b>7.44 (4.70, 10.17)</b>	<b>0.001</b>
Frequency of eating out				
Low	Ref		Ref	
Medium	<b>-4.96 (-7.46, -2.45)</b>	<b>0.001</b>	<b>-5.08 (-7.49, -2.68)</b>	<b>0.001</b>
High	<b>-5.74 (-8.34, -3.14)</b>	<b>0.001</b>	<b>-6.64 (-9.19, -4.09)</b>	<b>0.001</b>

was linked with reduced per capita food expenditures... reduced away-from-home expenditures (\$133 and \$68... frequent eating out was associated with significantly higher expenditures (p=0.001), and higher away-from-home expenditures.

**CONCLUSIONS:** Home-cooked dinners were associated with lower per capita food expenditures. By contrast, frequent eating out was associated with higher per capita food expenditures and was a component of nutrition resilience.

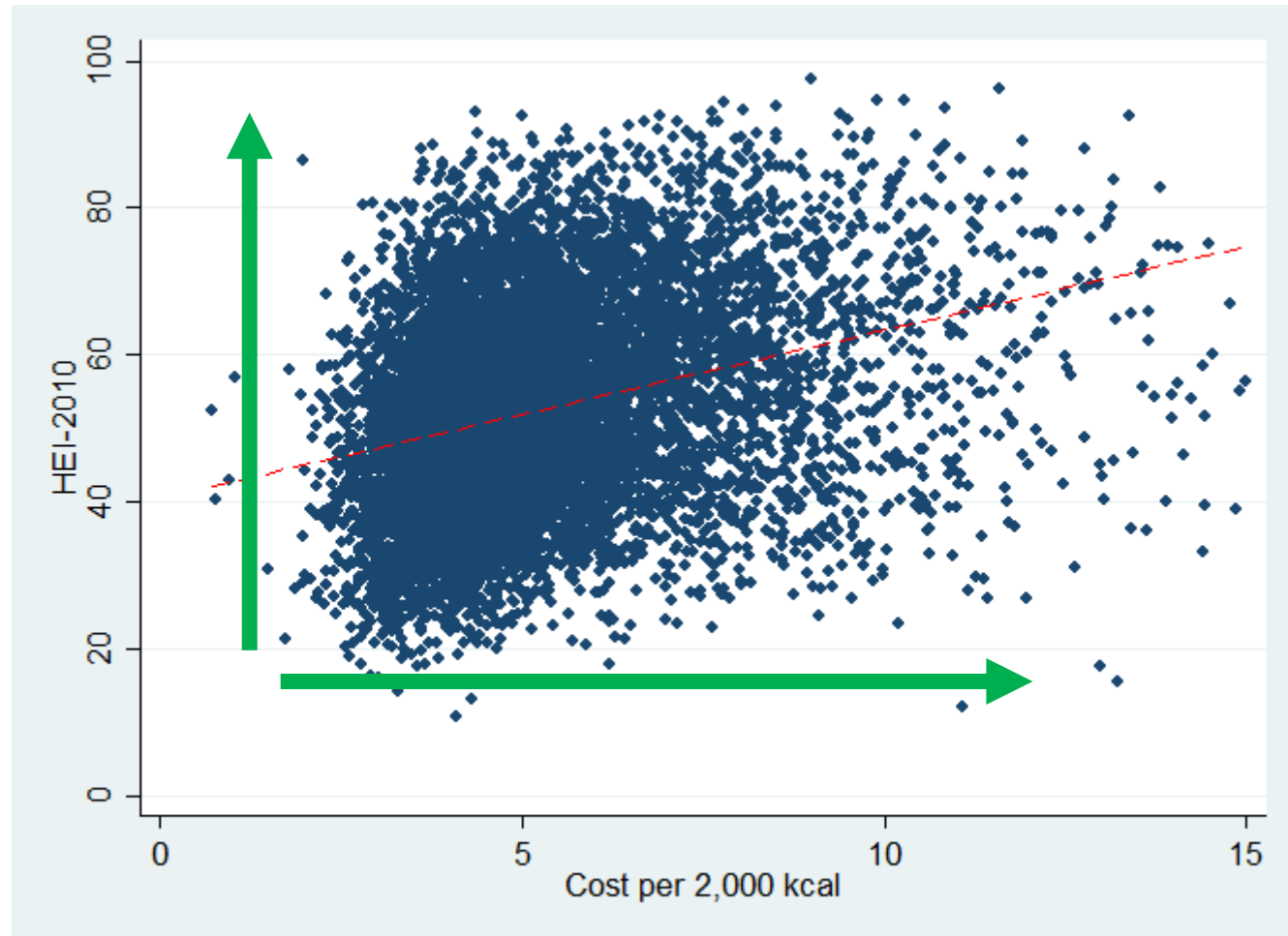
Copyright © 2017 American Journal of Preventive Medicine

PMID: 28256283 PMCID: PMC5401643 [Available on 2018-05-01]

Variable	Low (0-3/week)	Medium (4-5/week)	High (6+ /week)	p-value
Frequency of cooking dinner at home (N=437)	n=66	n=150	n=221	
Per capita food expenditures (\$/month)				
Total	330 (18.4)	291 (21.5)	273 (10.4)	<b>0.033</b>
At home	195 (13.6)	180 (7.8)	208 (8.3)	0.051
Away from home	133 (11.9)	108 (7.8)	65 (16.3)	<b>0.001</b>
Frequency of eating out (N=437)	n=281	n=77	n=79	
Per capita food expenditures (\$/month)				
Total	261 (8.5)	305 (18.7)	364 (19.7)	<b>0.001</b>
At home	196 (6.8)	202 (13.1)	193 (13.1)	0.895
Away from home	64 (3.4)	101 (8.2)	171 (12.5)	<b>0.001</b>

# Good news!

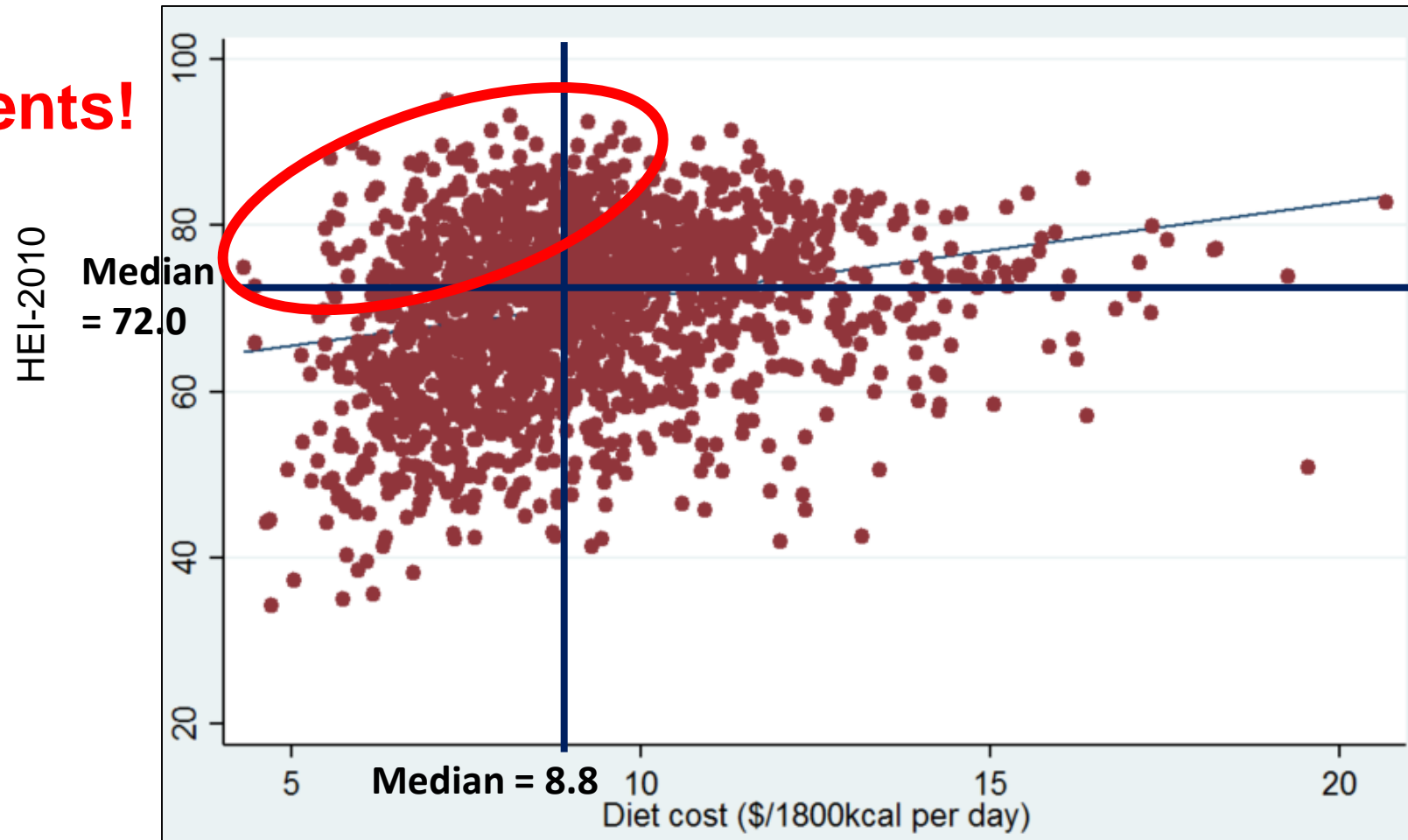
Healthier diets need not cost more. There is a huge variability in diet quality at every level of cost



# Evidence from SOS data

## The concept of nutrition resilience

**Resilients!**



# The concept of nutrition resilience

[Prev Med](#). 2016 Sep;90:184-92. doi: 10.1016/j.ypmed.2016.06.030. Epub 2016 Jun 29.

## Importance of taste, nutrition, cost and convenience in relation to diet quality: Evidence of nutrition resilience among US adults using National Health and Nutrition Examination Survey (NHANES) 2007-2010.

[Aggarwal A](#)<sup>1</sup>, [Rehm CD](#)<sup>2</sup>, [Monsivais P](#)<sup>2</sup>, [Drewnowski A](#)<sup>2</sup>.

### ⊕ Author information

#### Abstract

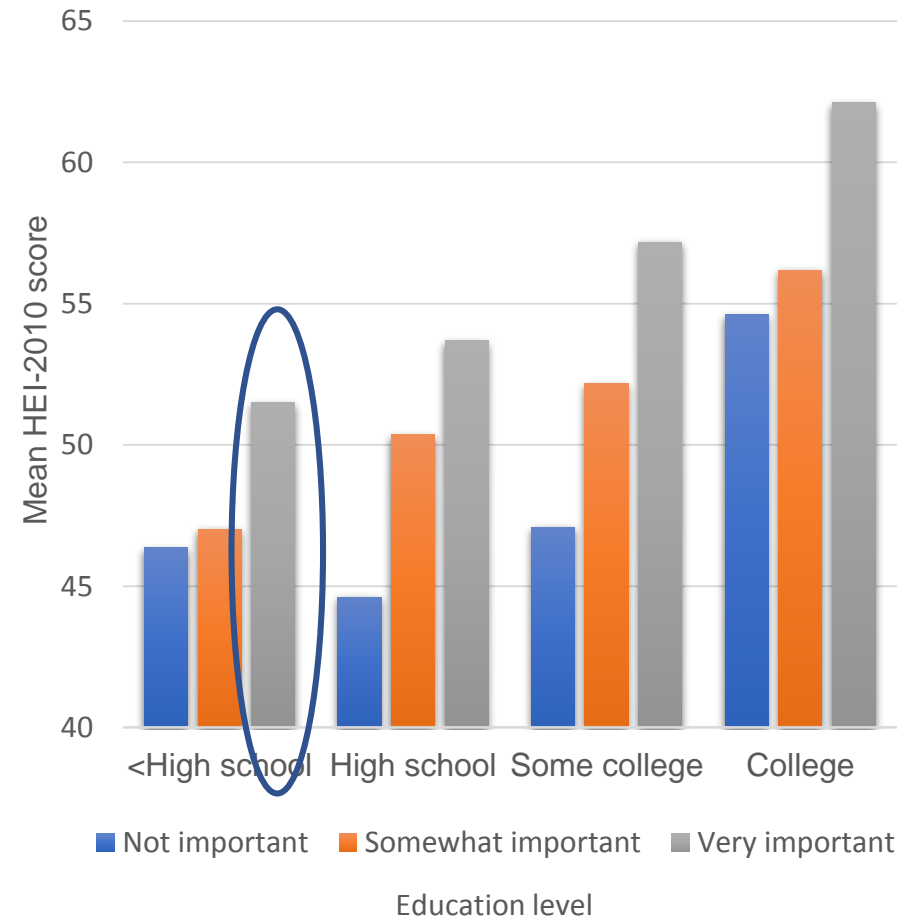
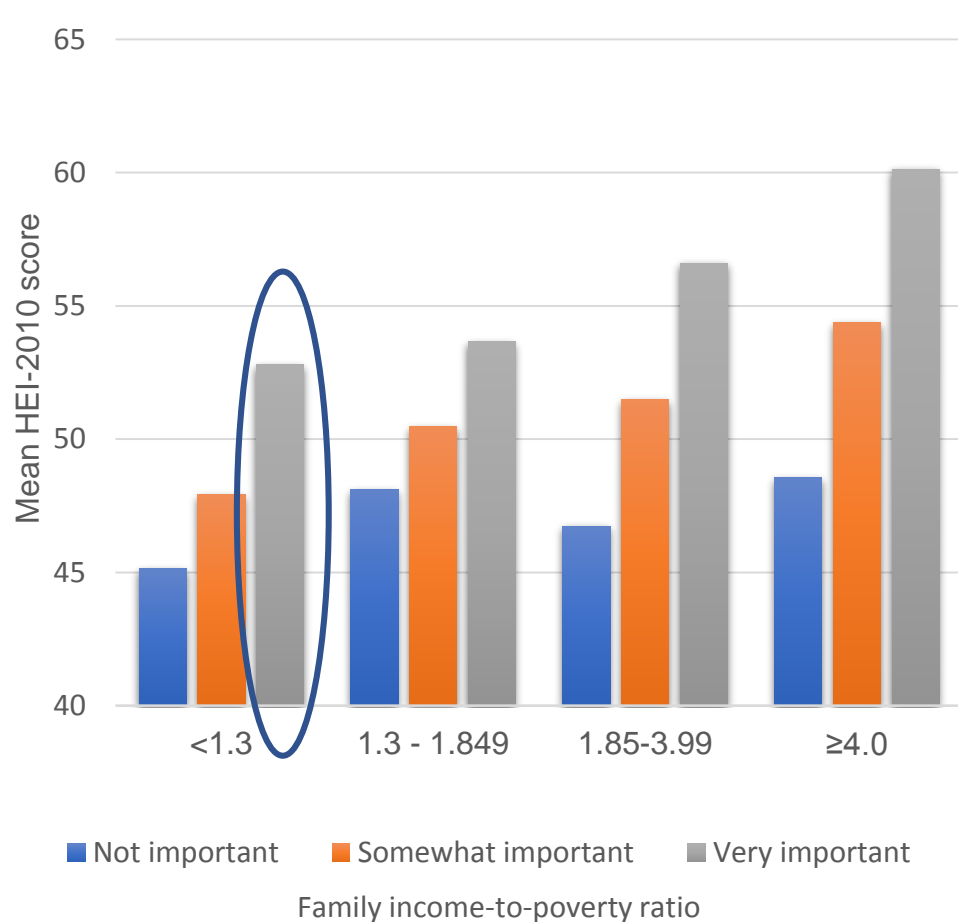
Concerns with taste, nutrition, cost, and convenience are said to be key influences on food choices. This study examined the importance of food-related attitudes in relation to diet quality using US national level data. Interactions by socioeconomic status (SES), gender and race/ethnicity were tested. Analyses of 8957 adults from National Health and Nutrition Examination Survey (NHANES 2007-2010) were conducted in 2014-15. Perceived importance of taste, nutrition, cost, and convenience in dietary choices were assessed using 4-point Likert scales. Education and family income-to-poverty ratio (FIPR) were SES indicators. Healthy Eating Index (HEI-2010), a measure of adherence to 2010 dietary guidelines, was the diet quality measure. Survey-weighted regressions examined associations between attitudes and HEI, and tested for interactions. Taste was rated as "very important" by 77.0% of the US adults, followed by nutrition (59.9%), cost (39.9%), and convenience (29.3%). However, it was the perceived importance of nutrition that most strongly predicted HEI ( $\beta$ : +8.0 HEI scores among "very important" vs. "not at all important"). By contrast, greater importance for taste and convenience had a weak inverse relation with HEI ( $\beta$ : -5.1 and -1.5 respectively), adjusting for SES. Significant interactions were observed by race/ethnicity, but not SES and gender. Those who prioritized nutrition during food shopping had higher-quality diets regardless of gender, education and income in the US. Certain racial/ethnic groups managed to eat healthy despite attaching importance to cost and convenience. This is the first evidence of nutrition resilience among US adults using national data, which has huge implications for nutrition interventions.

Published by Elsevier Inc.

Evidence from NHANES

# Having the right attitude is linked with higher quality diets at all levels of income and education, NHANES 2007-10

“When you buy foods from grocery store or supermarket, how important is nutrition”



# Summary

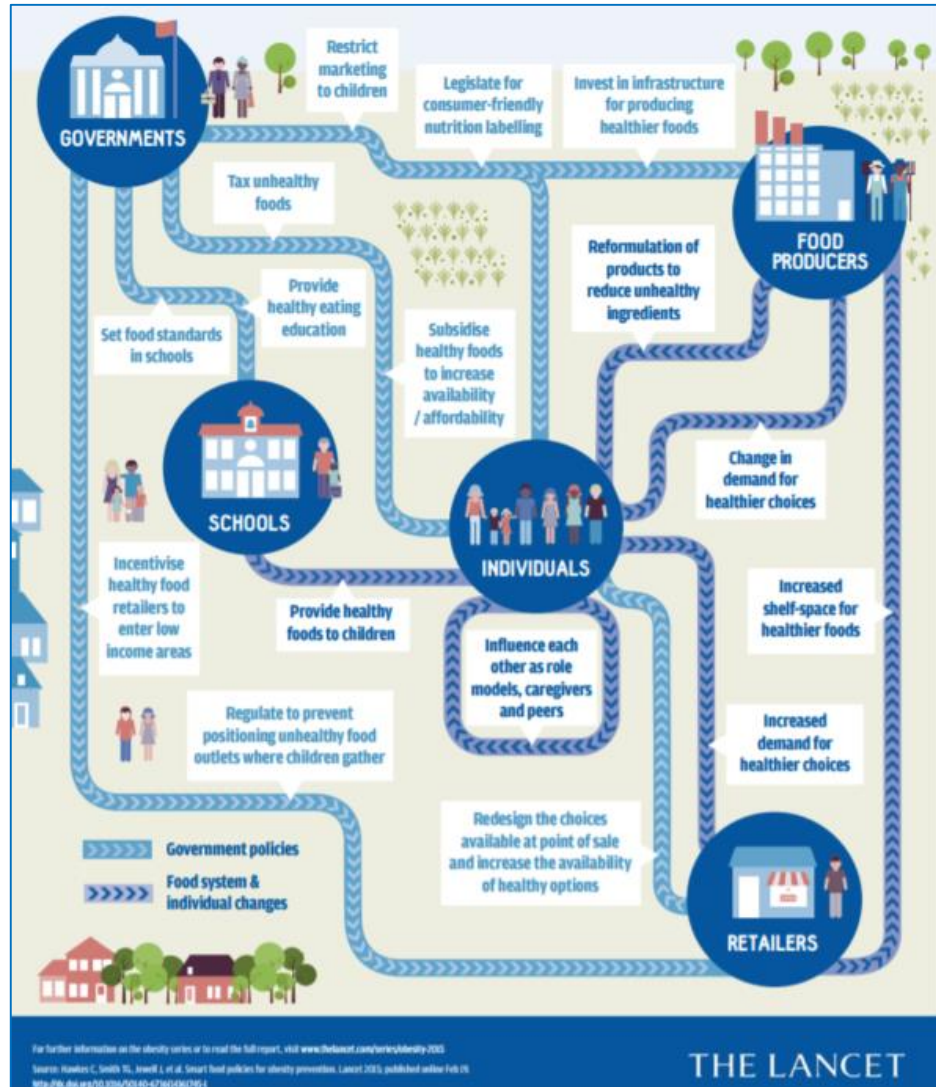
1. Toolbox of metrics provided in-depth understanding of the food environment in King County
  - Individual-level estimates of diet cost (economics)
  - Physical distances to food shopping destinations (geographic access)
  - Food-related attitudes and practices (psychosocial access)
  - Nutrition resilience (interactions)
2. Deployed the toolbox in suburban and rural Counties, WA State.

## Next steps

1. Scale up the toolbox of metrics to low and middle income countries.



# Our metrics toolbox aligns with the Lancet 2015 scheme



The food system is an interconnected network of producers, industry and institutions. But its heart is the individual.

Lancet Obesity 2015 series. explored

- ✓ Activities in the food system (production, distribution, storage, marketing)
- ✓ Food prices and economic barriers
- ✓ Geographic barriers
- ✓ Importance of food preferences and psychosocial barriers
- ✓ Interactions among all



# THANK YOU

**Anju Aggarwal**

anjuagg@u.washington.edu

