Pilot Study: Nutrition environment quality of patronized stores compared to diet quality of patrons intakes: impact of socioeconomic status

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**Table of Contents**

[Introduction 3](#_Toc432774112)

[Review of Literature 6](#_Toc432774113)

[1. Food Choice 6](#_Toc432774114)

[A. Levels of influence on food choice 6](#_Toc432774115)

[B. Factors within levels that affect food choice 6](#_Toc432774116)

[1. Socioeconomic status 7](#_Toc432774117)

[II. Measurement Tools for Diet Quality of Individual and Food Store Environment 9](#_Toc432774118)

[A. Measuring diet quality of the individual 9](#_Toc432774119)

[1. HEI 2005 11](#_Toc432774120)

[2. HEI 2010 11](#_Toc432774121)

[3. AHEI 12](#_Toc432774122)

[B. Measures of the food store environment 15](#_Toc432774123)

[1. NEMS tool 16](#_Toc432774124)

[**a.** **Reliability and validity of NEMS-S** 16](#_Toc432774125)

[**b.** **Sensitivity of NEMS-S tool** 17](#_Toc432774126)

[2. HEI 2005 18](#_Toc432774127)

[III. Food Environment and SES Influence on Food Choice 19](#_Toc432774128)

[A. Grocery store assessment 19](#_Toc432774129)

[IV. Conclusion 20](#_Toc432774130)

[Methods 21](#_Toc432774131)

[Study Setting/Design 21](#_Toc432774132)

[Population and Selection Criteria 21](#_Toc432774133)

[Neighborhood Selection 22](#_Toc432774134)

[Diet Measures 22](#_Toc432774135)

[Food Environment Measures 23](#_Toc432774136)

[Pilot Study Measuring Inter-Rater Reliability 23](#_Toc432774137)

[Sample Size 24](#_Toc432774138)

[Statistical Analysis 24](#_Toc432774139)

[References 26](#_Toc432774140)

[Table 1. Differences between HEI-2005, HEI-2010, and AHEI-2010 Components and Scoring Criteria 29](#_Toc432774141)

[Table 2. Evaluation of Components of HEI and AHEI to Food Availability Constructs in Nutrition Environment Measures 31](#_Toc432774143)

[Table 3. Composite scores for healthy nutrition environments by neighborhood SESa 32](#_Toc432774144)

[Figure 1. Concentric circles of influence on eating behaviors. 33](#_Toc432774145)

# Introduction

There are many factors that influence diet quality, but possibly one of the most important factors is the food environment. The food environment is very complex and provides an array of nutrition choices at each level. Giddings et al (2009) represented the multi-level food environment as concentric circles that start with the individual level at the center surrounded by the family environment, then the *microenvironment*, and lastly enclosed by the *macroenvironment* (**Figure 1**). The individual level refers to the biological, genetic, and demographic factors in a person whereas the family environment refers to the food behaviors modeled by other family members, culture, and food availability within the home. The *microenvironment* level refers to the local surrounding of the family including restaurants and fast food outlets, schools, and worksites, while the *macroenvironment* level refers to the economic and government policies, laws, and industry relations. By displaying the food environment in circles that overlap, a change in one level can impact other levels within diet quality of the individual intake {{19 Gidding,S.S. 2009;}}. For this study, the focus will be on the portion of the *microenvironment* that includes the stores around the home where food has been purchased along with the individual level where food choice is made {{19 Gidding,S.S. 2009;}}.

Food environment may influence food choice and thus ultimately, the dietary quality of an individual. There are numerous measurement tools used to assess an individual’s dietary quality. A few common tools include the Healthy Eating Index (HEI-2005 and 2010) along with the Alternative Healthy Eating Index (AHEI-2010). The HEI measures the compliance to the evidenced based guidelines developed by the US government called the Dietary Guidelines of Americans (DGA) and the AHEI-2010 is a modified version of the HEI-2010 {{114 U.S. December 2010;}}. The overall goal of using these measurements is to get a general idea of what dietary characteristics are present or lacking in individual’s diets so that improvements in these areas can be made.

Another factor that may influence diet quality is socioeconomic status (SES), defined here as household income, as done by Glanz et al {{8 Glanz,K. 2007;}}. Those with a lower income may not be able to afford the healthier, higher priced options and this price gap may influence what type of food one is able to purchase {{105 Darmon 2008;}}. Household income is defined as the average income from all persons in the home above the age of 15 years old, related or not (http://quickfacts.census.gov/qfd/meta/long\_INC110213.htm). For this study, we will be using median household income defined by neighborhood. The location and type of the stores available may influence the types of foods purchased. Those in a lower SES neighborhood may not have access to stores that provide healthy food options or the quality of these options may not be adequate. Another explanation is that although healthy foods may be available in the stores, the location of grocery stores or restaurants themselves may not be available, known as “food deserts” {{105 Darmon 2008;}}.

There are many factors in the food environment that can influence the dietary quality of individuals. SES is a big contributor to how the food environment and dietary quality interrelate. Thus, the purpose of this study is to examine if neighborhood SES correlates with a measure of the food environment patronized and quality of diets consumed by participants in SHoPPER (Study of Household Purchasing Patterns, Eating and Recreation). The main objectives of this study include the following:

Objective 1: *To determine if the diet quality operationally defined by HEI-2010 scores differs by neighborhood SES.*

Objective 2: *To determine if the food environment operationally defined by scores from NEMS-S (supermarkets) differs by neighborhood SES.*

# Review of Literature

## Food Choice

### Levels of influence on food choice

As mentioned earlier, Giddings et al. (2009) provided a multilevel framework that describes the various levels of influence on food choice **(Figure 1)**. The levels are depicted in concentric circles that start with the individual level at the very center surrounded by the family environment, then the *microenvironment*, and lastly enclosed by the *macroenvironment*. For this study, the present investigator will refer to the food environment at the *microenvironment* level along with that of the individual and family environments included within as described by Giddings et al. (2009) {{19 Gidding,S.S. 2009;}}.

### Factors within levels that affect food choice

The factors that influence food choice are complex and multifactorial. Some factors that affect food choices can be changed, or modified, by the individual, while some are beyond the control of the individual, or non-modifiable. There are many modifiable factors that influence food choice such as the desire to consume healthy foods, the motivation to choose healthier foods over unhealthy foods, the knowledge of which healthier foods to choose, and individual taste preferences. Non-modifiable influences include the marketing and media influence, price of food, the availability and accessibility of the healthy food, the race/ethnicity of the individual, and socioeconomic status (income); however, this study will focus primarily on the latter influence.

#### Socioeconomic status

In a review conducted by Darmon et al. (2008), the researchers defined SES variably to include occupation, education, and/or income levels. According to Darmon et al. (2008), “A large of body of epidemiologic data show that diet quality follows a socioeconomic gradient” {{105 Darmon 2008;}}. Since SES can influence food choice, this may impact an individual’s overall diet quality. To investigate this idea, the researchers analyzed numerous cross-sectional studies to determine if diet quality was associated with SES (estimated a number of different ways, either as education, income, and/or occupation).

 These researchers observed that certain foods and nutrients are included in the diet of those with a higher SES and not included in the diet of those with a lower SES. Specifically, those with a higher SES had a higher intakes of whole grains, lean meat, fish and other seafood, and low-fat milk versus those with lower SES who had higher intakes of refined grains, starchy vegetables, especially potatoes, fatty/fried meats, whole milk, and overall, higher fat intake {{105 Darmon 2008;}}. Higher SES participants had consistently higher intakes of most vitamins, minerals, and fiber when compared to lower SES groups. Currently, there is no consistent evidence that energy intake or macronutrient consumption differ significantly across SES {{105 Darmon 2008;}}. The relationship between diet quality and SES is still being researched, and the proposed study will help clarify the relationship further.

In a study conducted by Wang et al. (2014), researchers looked at how diet quality was modified by SES. SES was defined as a composite of two measures including the following: 1) income level (reflected as poverty income ratio or PIR) and 2) number of completed college years to classify education. The authors defined the cutoffs for low SES (<1.30 for PIR and <12 years education achievement) and high SES (≥3.50 for PIR and ≥12 years education achievement).[[1]](#footnote-1) Two 24-hour recall data were used from six consecutive two-year cycles in NHANES participants from 1999-2010, representing a population of almost 30,000 participants aged 20-85 years, along with demographic information to divide participants into socioeconomic educational strata. Dietary quality was assessed using the Alternate Healthy Eating Index 2010 (AHEL-2010), a tool developed by Harvard researchers based on their own research to assess diet quality with scores ranging from 0-110 points (the higher the score, the better the diet quality). Wang et al. (2014) observed that participants with high SES showed greater improvement in AHEI-2010 scores than participants with low SES and the gap between low and high SES widened over time (from 3.9 points in 1999 to 2000 to 7.8 points in 2009 to 2010, p=0.01). Another diet quality score, the HEI-2010 was also used and a similar trend, but not significant to the AHEI, was observed (the gap between low and high SES increased over the 10 years). Lack of improvement in diet quality among participants of lower SES further demonstrates how dietary quality is not getting better in the population subgroups that would benefit from improvement the most {{21 Wang,D.D. 2014;}}.

These authors suggested that those with a lower income may not own a car and therefore may not have access to supermarkets that carry healthier foods. Education level may also influence diet quality. Those with less education may not know what is nutritious and advantageous to improve their overall diet quality. Also, healthier foods sold in the food environment may cost more than unhealthier foods, forcing people with a low-income to purchase lower quality foods {{21 Wang,D.D. 2014;}}.

Another way to approach this model rather than using individual SES is to assess the SES of the neighborhoods. Neighborhoods are often operationalized by U.S. census tracts, which provide predefined areas and various demographic information such as income level, population, and number of food stores. Similar study investigators have utilized the census tracts to compare SES of specific neighborhoods such as Glanz et al. (2007) and will be discussed later in this paper {{8 Glanz,K. 2007;}}.

Socioeconomic status is just one of many factors that influence the food environment surrounding individuals and that ultimately influence food choices people make. Moreover, there are many different ways SES is defined. So individual choice, hence diet quality, may be the result of poor choices made at food stores in the microenvironment. There are studies that suggest food choices are predicted by the food environment quality and that SES influences this relationship. However, before we can look at this impact later discussed in section three, we first have to determine how to measure both diet quality and food environments.

## Measurement Tools for Diet Quality of Individual and Food Store Environment

Various measurement tools can be used to determine how the food environment and diet quality are influenced by various factors including SES.

### Measuring diet quality of the individual

A common tool used to measure diet quality is the Healthy Eating Index (HEI). It measures diet quality by examining compliance to the Dietary Guidelines for Americans (DGA) {{114 U.S. December 2010;}}, which are evidenced-based guidelines developed by the US government. These DGA are converted into specific intake recommendations of the amount and type of foods at 12 different calorie levels by the US Department of Agriculture (USDA) Food Patterns. These recommendations created by the USDA Food Patterns are used to establish the scoring values for the HEI-2010 {{77 Guenther,P.M. 2013;}}. The USDA and US Department of Health and Human Services publish the DGA every five years. The DGA 2005 and 2010 included the Dietary Approach to Stop Hypertension (DASH) diet plan in addition to the USDA Food Patterns. The DASH diet incorporates more fruits, vegetables, low-fat dairy products, and whole grains and less saturated fatty acids, added sugars, and refined grains compared to the normal American diet. The HEI-2005 was updated to the HEI-2010 to include the changes in recommendations made by the USDA Food Patterns and the 2010 DGA {{77 Guenther,P.M. 2013;}}. In 2002, the Alternative Healthy Eating Index (AHEI) was developed by modifications of the HEI by the Harvard group and included food components predictive of the incidence of chronic disease in several cohorts {{100 McCullough,M.L. 2002;}}. The AHEI was updated in 2012 and was named the AHEI-2010, which includes more up-to-date scientific evidence on diet and disease development {{102 Chiuve,S.E. 2012;}}.

Three variations of the HEI tool (the HEI-2005, HEI-2010, and AHEI-2010) include different components and recommended amounts along with different scoring criteria. The different components and scoring criteria between the tools are described in **Table 1**. Note that for each component listed, maximum points are on the left hand side of the columns. The optimal score for the HEI-2005 and 2010 is 100 points and for the AHEI-2010, 110 points. Maximum points are only given if the target servings to achieve the maximum score are met. However, it should be noted that the target number of servings for the maximum score differ among the three tools. Components of the tools are categorized by food group, with some described in further detail in **Table 1**.

#### HEI 2005

The HEI-2005 has been evaluated for construct and content validity by Guenther et al. (2008) using one 24-hour food recall from each participant from NHANES 2001-2002. Researchers evaluated validity in several ways including the following: 1) face validity (whether maximum HEI-2005 scores are achieved in four sample menus known to have high diet quality including MyPyramid, the DASH Eating Plan, Harvard’s Healthy Eating Pyramid, and the American Heart Association’s No-Fad Diet); 2) discriminative validity (whether the HEI-2005 scores of diets of smokers differ from those of nonsmokers); and 3) concurrent validity (whether diet quality is independent of quantity, measured by energy intake, when comparing the total score of the food components to the energy). In addition, researchers evaluated whether each of the 12 components independently contribute to the variance in overall diet quality. The researchers found that the four menus reached almost maximum scores, smokers had a lower mean score than nonsmokers (44.7 compared to 53.3; p<0.01), scores were independent of energy intake, and there were multiple factors that contributed to the HEI-2005 score. Researchers concluded that there is strong evidence that the HEI-2005 is a valid measure of diet quality {{107 Guenther,P.M. 2008;}}.

#### HEI 2010

 The HEI-2010 is the most up-to-date version that incorporates the 2010 Dietary Guidelines for Americans (DGA). As seen in **Table 1**, changes made from the HEI-2005 that are incorporated into the HEI-2010 include the following: 1) dark-green and orange vegetables and legumes was replaced with greens and beans; 2) total grains was replaced by refined grains; 3) meat and beans was replaced by seafood and plant proteins and total protein foods; 4) fats were categorized as fatty acids and long chain (ω-3) fats (EPA + DHA) instead of as saturated fat and oils; and 5) calories from solid fat, alcohol and added sugar (SoFAAS) was replaced with empty calories {{77 Guenther,P.M. 2013;}}. Target amounts remained consistent for the component groups that stayed the same, except for sodium, which increased from ≤0.7 in the HEI-2005 to ≤1.1grams/1,000 kcal in the HEI-2010.

There are advantages and disadvantages to using the HEI-2010. Advantages include that it is designed to measure the diet of all Americans age ≥2 years. However, thus far the scoring paradigm has not been validated specifically among different ethnic and cultural groups. However, Guenther et al. (2013), stated that it can be assumed to be valid since mixed dishes specific to certain ethnic and cultural groups can be separated into specific components {{77 Guenther,P.M. 2013;}}. Also, it can be assumed to be valid because it has been applied to national probability samples (NHANES data) and thus should account for the racial and ethnic diversity of the American population {{21 Wang,D.D. 2014;}}. According to Guenther et al. (2013), “like the HEI-2005, the HEI-2010 can be used to assess changes in diet quality over time, and evaluate the diets of subpopulations, food environments, menus, foods provided through the USDA nutrition assistance programs” {{77 Guenther,P.M. 2013;}}.

#### AHEI

The diet quality tool used by Wang et al. (2014) was originally developed by McCullough et al. (2002) who modified the HEI components to develop a 9-component Alternative Healthy Eating Index (AHEI) (the original AHEI) that contains food components associated with decreased likelihood of developing chronic diseases {{100 McCullough,M.L. 2002;}}. Researchers compared the ability of the AHEI and the HEI to predict disease risk using food frequency questionnaire data collected from two large studies of health professionals. AHEI scores were based on foods present in the Harvard 130 item food frequency questionnaire. Major chronic disease was defined as the first occurrence of cardiovascular disease (myocardial infarction, stroke, or sudden death), cancer, or non-trauma-related death. When comparing the lowest to the highest quintiles, high AHEI scores were associated with a lower risk of major chronic disease development in men [multivariate relative risk (RR): 0.80; 95% CI: 0.71, 0.91] and in women [RR: 0.89; 95% CI: 0.82, 0.96]. According to further analyses by McCullough and coworkers (no data provided), “when the AHEI and the HEI were included in the same model, the AHEI scores were predictive of major chronic disease development (p=0.005 for men and p=0.01 for women), while the HEI scores were not”. These researchers concluded that participants whose diet closely matched the AHEI goals had a lower risk for developing a major chronic disease (20% for men and 11% for women). Also, those who received a high AHEI score had a lower risk of developing cardiovascular disease [39% in men (RR = 0.61; 95% CI: 0.49, 0.75) and 28% in women (RR = 0.72; 95% CI: 0.60, 0.86)] than those who received a low AHEI score, but no association was made for cancer risk {{100 McCullough,M.L. 2002;}}.

Similar studies to McCullough et al. (2002) have shown associations between high AHEI-2010 scores and reduced risk for other diseases such as heart failure, total and cardiovascular mortality, diabetes, colorectal and estrogen-receptor-negative breast cancer {{102 Chiuve,S.E. 2012;}}. Researchers looked at incident of diabetes, cancer, cardiovascular disease, or nontrauma death among 40,000 men and women following the Nurses’ Health Study and the Health Professionals Follow-Up Study. Researchers found that when comparing the highest to the lowest quintile, the HEI-2005 was associated with a relative risk or RR (95% CI) of chronic disease of 0.84 (0.81, 0.87) and the AHEI-2010 was associated with a RR of chronic disease of 0.81 (0.77, 0.85). Researchers also found that both the HEI-2005 and the AHEI-2010 were inversely related to risk of incident chronic disease (including diabetes, coronary heart disease, stroke, and total cancer). Based on the Wald test, the AHEI-2010 was found to be more strongly associated with coronary heart disease and diabetes than the HEI-2005 (P-difference = 0.002 and <0.001) {{102 Chiuve,S.E. 2012;}}.

According to Wang et al. (2014), the construct validity of the AHEI-2010 has been demonstrated against the following: major chronic disease risk (as previously mentioned by Chiuve et al. (2012)); biomarkers of inflammation and endothelial function as well as mortality {{21 Wang,D.D. 2014;}}. Also, the HEI-2005 has been previously associated with inflammatory biomarkers {{113 George,S.M. 2010;}}.

In summary, there are multiple up-to-date methods to measure diet quality of individuals. Both the HEI and AHEI were developed by different groups with different aims. The HEI-2005 was developed by the government based more on the DGA rather than data derived from specific cohorts and it took a few years for investigators to tie the tool to outcomes, whereas the AHEI-2010 was developed by a group of investigators that modified the HEI-2010 data using the results obtained by their own research. Also, to collect dietary data, the HEI was developed and tested using 24-hour dietary recalls that are open ended and may allow for accurate representation of intake, whereas the AHEI investigators used the food frequency questionnaires (FFQs) that may not include all possible foods a person consumes. Because the proposed effort will use 24 hour recall data, the principal investigator will be using the HEI-2010 tool to measure dietary quality.

### Measures of the food store environment

 According to the National Cancer Institute, the food environment can be measured in two ways, either by an instrument or a methodology. There are four different instruments used to measure the food environment. These include 1) a checklist that contains a list of foods to be identified by researchers, 2) an interview/questionnaire that includes a list of questions administered by trained researchers or completed by subjects themselves, 3) an inventory that uses a form to record all foods present in the environment, and 4) a market basket that includes a pre-defined list of foods representative of different food choices across an entire diet that may reflect a specific population consumption pattern or a standardized plan such as the USDA’s Thrifty Food Plan. Instruments are normally standardized tools that are paper-based and are completed by researchers or subjects (http://appliedresearch.cancer.gov/mfe/). The market basket instrument (specifically the Nutrition Environment Measures Survey or NEMS) will be used in this study to gather data on what foods are frequently consumed by residents in the Chicago area.

 Currently, there are various tools being used to measure the food *microenvironment,* or the immediate environment around a person’s home. The two tools this paper will focus on include the Nutrition Environment Measures Survey (NEMS) of stores and the HEI-2010. The NEMS tool has been used in urban environments that contained an ethnically diverse population. Details about the scoring of each food category in the NEMS tool related to the components of the HEI and AHEI are listed in **Table 2**.

#### NEMS tool

Glanz and coworkers created NEMS to assess the community and consumer nutrition environment (www.med.upenn.edu/nems). Numerous variations to the NEMS tool have been created to assess different components of the *microenvironment* and include the NEMS Restaurant Measure (NEMS-R), the NEMS Store Measure (NEMS-S), the NEMS Corner Store Measure (NEMS-CS), and the NEMS Vending Tool (NEMS-V). For this study, the store environment will be specifically measured; therefore, the NEMS-S measure will be used. As shown in **Table 3**, each of the three components to NEMS-S has a possible score of 30, 6, and 18 for availability, quality, and price respectively. The scoring process for each food category of the NEMS-S tool is slightly different (for details of the availability scoring, refer to **Table 2**). There is an online training available for researchers interested in using the NEMS tool to ensure that the raters use and/or adapt the measures properly (www.med.upenn.edu/nems). Most of the validation studies have been conducted for each of the NEMS tools, the most seen in the NEMS-S tool.

##### **Reliability and validity of NEMS-S**

Glanz et al. (2007) assessed reliability of the NEMS-S based on data gathered in four different neighborhoods in the Atlanta metropolitan area independently by two researchers; one of the researchers also gathered data from the same retail store within one month of previous assessment to assess test-retest reliability. Inter-rater reliability was high as evidenced by percent agreement of 92%-100% and kappa 0.83-1.00. Test-retest reliability was also high as evidenced by percent agreement of 90.2%-100% and kappa 0.75-1.00. The 10 food categories scored were based off of authoritative recommendations, giving the tool face validity. Researchers concluded that the NEMS-S tool has high inter-rater and test-retest reliability along with high face validity {{8 Glanz,K. 2007;}}.

##### **Sensitivity of NEMS-S tool**

Not only is the NEMS tool valid and reliable, it also appears to be sensitive enough to determine small differences between groups. Glanz et al. (2007) used the NEMS-S tool to determine the nutrition environment in retail stores and distinguish if a difference existed in nutrition environments among different stores and between low and high-income neighborhoods defined as one census tract (determined using the 2000 Census data) {{8 Glanz,K. 2007;}}. Researchers found that low-income areas (n=41) had lower mean NEMS-S scores when compared to high-income areas (n=44) (7.8±7.6 vs. 13.1±10.2). However, results cannot be generalized because only one metropolitan area was studied {{8 Glanz,K. 2007;}}.

In another study conducted by Cannuscio et al. (2013), researchers examined the influence of various grocery store sizes on food quality using the NEMS-S tool. The 373 stores were classified as large chain supermarkets and big box (e.g. Target, Wal-Mart) (n=54); medium, nonchain grocery stores (>3 aisles; >1 register) (n=15); corner and convenience stores (one register only) (n=293); and specialty shops and produce stores (n=11){{110 Cannuscio,C.C. 2013;}}. Researchers found that mean NEMS-S scores for each store type differed (p<0.05) with large chain supermarkets scoring the highest at 38.4 (7.6) (mean (SD)), medium grocery stores scoring 21.7 (4.8), other stores scoring 15.6 (5.7) and corner and convenience stores scoring the lowest at 11.1 (6.1). Most participants (n=461; 89.3%) lived closest to corner and convenience stores and only 3 participants (0.6%) lived near large chain supermarkets. These results suggest that participants lived closer to stores that carried less healthy options. However, this study was conducted in only one, large metropolitan area and therefore cannot be generalized to the public at large. Even with this limitation, the results imply that the NEMS-S tool is sensitive to enough to determine differences in nutrition environments of grocery stores as a function of their size. {{110 Cannuscio,C.C. 2013;}}.

#### HEI 2005

Another way to assess the quality of the food environment is through the use of HEI-2005. In a study conducted by Reedy et al. (2010), researchers assessed the application of the HEI-2005 in the food environment using the dollar menu from a fast-food chain (representing the community level) and the 2005 U.S. food supply (representing the *macroenvironment* level). An algorithm was used to derive the total HEI-2005 score. The dollar menu from a fast-food chain scored a 43.4 out of 100 points and the 2005 U.S. Food Supply scored a 54.9 out of 100 points. These results align with the hypothesis that the fast-food chain would have an unhealthier rating than the U.S. Food Supply. Since the HEI-2005 scores are based on density and use a single set of standards, the HEI-2005 tool can be used not only to assess individual diets, but also food environments {{18 Reedy,J. 2010;}}.

There are limitations of the use of the HEI-2005 in the market nutrition environment. One reason for these limitations is that the HEI-2005 focuses mainly on nutrient content rather than whole food items. Therefore, the HEI-2005 may not accurately reflect the market nutrition environment. This may also be true for the newer version, HEI-2010 where multiple food categories are not included in the nutrition environment measures.

In conclusion, the food environment provides a complex array of nutrition choices because of the intricacy of its levels and allows for numerous measurement techniques to be applied. Although the HEI can be used to measure the food environment, this study will be using the NEMS-S tool since it was developed specifically to examine the food store environment, contains more food options found in food stores, and is more commonly used in the literature.

###  Food Environment and SES Influence on Food Choice

### Grocery store assessment

As stated previously, Glanz et al. (2007) looked at the nutrition environment in low and high socioeconomic status (SES) groups, defined as low and high-income status. They used the NEMS-S tool to evaluate the food availability, quality, and price in grocery stores. The 2000 U.S. Census and regional land-use data were used to determine low and high SES groups. A total of 10 food categories including foods such as fruits, hot dogs, and baked goods were evaluated in 85 different food stores. Results for the nutrition environment scores by income level are shown in **Table 3**. Researchers found that there was higher healthy food availability[[2]](#footnote-2) in high-income areas versus low-income areas for all food types (10.2±9.2 vs. 4.4±5.7) {{8 Glanz,K. 2007;}}. Regarding the total nutrition environment scores, or NEMS-S, researchers found that low-income areas had lower mean NEMS-S scores when compared those in high-income areas (7.8±7.7 vs. 13.1±10.3). Although the availability, quality and total scores were higher in high-income areas compared to low-income areas, the price scores were lower; low-income areas had higher scores (lower prices for healthful foods) (0.3±2.4 vs. 2.0±1.1). However, given the small sample size and that the location of the study was conducted only in one metropolitan area, one cannot conclude that these observed differences in nutrition environments between SES and food store types would consistently occur {{8 Glanz,K. 2007;}}.

## Conclusion

In conclusion, there are many factors that influence individual food choices. A person’s diet quality can depend upon their food environment, their neighborhood SES status, and/or whether they have access or availability to healthier options. In order to improve diet quality, it is important to know where nutritional gaps lie (using the HEI-2010) and what underlying influences exists that enhance or mitigate these gaps (NEMS-S). To date, no one has examined individuals diet quality, HEI-2010, in relation to the income, whether income predicts NEMS-S, and the long-term objective to assess whether income mediates the putative relationship between NEMS-S and HEI-2010. The purpose of this study will to be to determine how income modifies the relationship between diet quality and food environment.

# Methods

## Study Setting/Design

This study is a substudy of an ongoing study called Delay Discounting and Household Food Choices or SHoPPER (Study of Household Purchasing Patterns, Eating and Recreation), with Dr. Brad Appelhans as the Principal Investigator at Rush University Medical Center in Chicago, IL. The substudy and the parent study are cross-sectional in design. The proposed substudy will be conducted to determine if there are differences in food environment (as measured by NEMS-S) and diet quality (HEI-2010) between persons of low and high SES (as defined by household income level) in SHoPPER study.

## Population and Selection Criteria

The target population of the parent study is household members who are the primary shoppers[[3]](#footnote-3) located in the city of Chicago, IL who were willing to collect food purchase receipts and be interviewed by the SHoPPER research team four times in a two-week period. During this time three 24-hour recalls were performed, with one day being a weekend day. As part of the study, participants were instructed to collect food receipts and complete supplementary forms with clearly identified locations. **For the substudy: all participants must have shopped at a grocery store identified on receipt data at least once in the 2-week data collection period. The minimum food items required to be present on receipt data will be determined as data are available.**

## Neighborhood Selection

Neighborhood selection will be based on SHoPPER purchasing data in context of the American Community surveyed data from the 2010 U.S. Census Tract. First, the street addresses of the grocery stores from participant ID food receipts will be entered into Access/Excel (Redmond, Washington, 2010) file. Second, all of the non-grocery store locations including restaurants, fast-food chains, farmers markets, etc. will be removed. Remaining data will be sorted according to store address (and participant ID). Then **median household income** for neighborhood census tracts will be overlaid or added using street address. Data will then be sorted by median household income of areas of above patronized stores and stratified into top 1/3 (or 1/5 depending on number of store types) and bottom 1/3 (or 1/5). Finally, five to seven stores will then be selected in the top and bottom strata (tertile/quintile). These stores will constitute the sample for which NEMS-S will be assessed by the environment investigators (HG and AB). Thus neighborhood SES is defined by 2010 US Census Tract household income strata.

## Diet Measures

The diet quality of the daily intake of the primary shopper in the household will be assessed using the HEI-2010. The daily intake is calculated from the averaged recall data from the three 24-hour diet recalls. Trained research personnel are collecting 24-hour recall data during home visits as by the SHoPPER protocol. The syntax to calculate the HEI-2010 and make comparisons was provided by Nutrition Data System for Research (NDS-R) and further modified by SHoPPER investigators (http://www.ncc.umn.edu/ndsrsupport/hei2010.pdf). Food purchase receipt data will be used to identify the location of grocery stores patronized by SHoPPER participants.

## Food Environment Measures

The quality of the food environment will be assessed using the NEMS-S tool in the selected stores. In order to use this tool, online training must be done with the NEMS-S protocol to receive certification. A test run using a sample of five stores will be conducted to ensure equivalent total NEMS-S scores do not differ between each research student to ensure inter-rater reliability. Scores for each of the three components of NEMS-S (availability, price, and quality) as well as the total score will be analyzed as described below under Pilot Study. Permission will be obtained verbally from all of the storeowners before data collection begins (letter of explanation will be presented if inquired).

## Pilot Study Measuring Inter-Rater Reliability

A pilot study will be conducted to determine the inter-rater reliability between NEMS-S scores of two research students completing this project, AB and HG. Five grocery stores[[4]](#footnote-4) located in close proximity to the research assistants’ homes will be assessed. Each research student will use the online data collection form to collect data. Both students will complete the NEMS-S tool at the same grocery store on the same day at the same time, starting at opposite ends as not to influence one another’s results. Data collection will also occur during the same time of the week to decrease chances of collecting data when stock is depleted. Once both research students complete all of the NEMS-S surveys, data will be imported into SPSS version 22 (IBM, Inc., 2013) for subsequent analysis. Spearman’s Rho will be calculated to determine the concordance in NEMS-S total and component scores (availability, price and quality) between the two raters. If rs is 0.7 or greater, the research students will be deemed to have high inter-rater agreement. If rs is less than 0.7, the research students will be re-trained and then the inter-rater reliability will be re-tested the same at five different grocery stores until such level of agreement is reached.

## Sample Size

The effect size was determined using results from a study conducted by Glanz et al. (2007) among four neighborhoods located in the Atlanta metropolitan area. The food environment (NEMS score) for Group 1 (high SES neighborhoods, n=44) was 13.14 ± 10.25 and for Group 2 (low SES neighborhoods, n=41) was 7.83 ± 7.66.- The expected difference in NEMS score was 5.31{{8 Glanz,K. 2007;}}. The alpha was set to 0.05 and the statistical power was set to 0.8. The G\*Power computer program was used to conduct a power analysis of the independent t-test. The calculation results indicated an effect size of 0.5868 and determined the total sample size needed to measure the effect is 94, where 47 stores are needed per group. Since we are conducting a pilot study, data will be collected from only 10-14 stores. With this small sample size, we will only have a power of 0.12-0.17 to find a difference in NEMS-S scores.

## Statistical Analysis

Descriptive statistics of categorical variables (gender, ethnicity, race, education and SES) and continuous (age, number of adults/children living the household, poverty threshold, income, on public assistance) will be presented for the two groups of primary shoppers, those in the low and those in the high-income census tracts. These characteristics will be analyzed for differences between low and high-income areas, using chi-square and t tests. The demographic continuous variables will be summarized using mean and standard deviations if normally distributed, or median and IQR, if not. Food environment and diet quality variables will also be analyzed using mean and standard deviations. All statistical data will be analyzed using SPSS 22 and a priori significance level equal to p<0.05.

Objective 1: *To determine if the diet quality operationally defined by HEI-2010 scores differs by neighborhood SES.* A t-test will be used to determine what difference exists in diet quality between low and high neighborhood SES. Further analysis will be performed using General Linear Model (GLM) to test for differences in HEI-2010 across the 2 income strata. Possible adjustments will be made (the number of covariates depend on the sample size).

Objective 2: *To determine if the food environment operationally defined by scores from NEMS-S (supermarkets) differs by neighborhood SES.* A t-test will be used to determine whether a difference exists in the food environment of stores/restaurants frequented by shopper participant between low and high neighborhood SES. Further modeling to correct for differences in covariates will be conducted.

The long term objective is to determine if differences are detected in HEI-2010 (objective 1) and NEMS-S (objective 2), further models will be performed to address the following questions:

*A) Does NEMS-S predict diet quality (HEI-2010)?*

*B) Does NEMS-S mediate the association between diet quality (HEI-2010) and SES?*

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| Table 1. Differences between HEI-2005, HEI-2010, and AHEI-2010 Components and Scoring Criteria |
| --- |
|  | **HEI-2005** | **HEI-2010** | **AHEI-2010** |
|  | **Maximum Points** | **Criteria** | **Maximum Points** | **Criteria** | **Maximum Points** | **Criteria** |
| **Component** | **Score of 0** | **Maximum Score** | **Score of 0** | **Maximum Score** | **Score of 0** | **Maximum Score** |
| FRUIT |  |  |  |  |  |  |  |  |  |
| Total Fruit (includes 100% juice) | 5 | 0 | ≥0.8 cups/1000 kcal | 5 | 0 | ≥0.8 cups/1000 kcal | … | … | … |
| Whole Fruit (not juice) | 5 | 0 | ≥0.4 cups/1000 kcal | 5 | 0 | ≥0.4 cups/1000 kcal | 10 | 0 | ≥ 4 servings/d |
| Sugar-sweetened beverages and fruit juice | … | … | … | … | … | … | 10 | ≥8 oz/d | 0 |
| VEGETABLES |  |  |  |  |  |  |  |  |  |
| Total Vegetablesa | 5 | 0 | ≥1.1 cups/1000 kcal | 5 | 0 | ≥1.1 cups/1000 kcal | 10 | 0 | ≥2.5 cups/d |
| Greens and beans | … | … | … | 5 | 0 | ≥0.2 cups/1000 kcal | … | … | … |
| Dark-green and orange vegetables and legumesb | 5 | 0 | ≥0.4 cups/1000 kcal | … | … | … | … | … | … |
| GRAINS |  |  |  |  |  |  |  |  |  |
| Whole grainsc | 5 | 0 | ≥1.5 oz/1000 kcal | 10 | 0 | ≥1.5 oz/1000 kcal | 10 | 0 | Women: 75 g/d; Men: 90 g/d |
| Refined grains | … | … | … | 10 | ≥4.3 oz/1000 kcal | ≤1.8 oz/1000 kcal | … | … | … |
| Total grains | 5 | 0 | ≥3.0 cups/1000 kcal | … | … | … | … | … | … |
| DAIRY |  |  |  |  |  |  |  |  |  |
| Milkd | 10 | 0 | ≥1.3 cups/1000 kcal | 10 | 0 | ≥1.3 cups/1000 kcal | 10 | 0 | ≥1.3 cups/1000 kcal |
| PROTEINS |  |  |  |  |  |  |  |  |  |
| Nuts and legumes | … | … | … | … | … | … | 10 | 0 | ≥1 oz/d |
| Red and/or processed meatse | … | … | … | … | … | … | 10 | ≥1.3 servings/d | 0 |
| Meat and beans | 10 | 0 | ≥2.5 oz/1000 kcal | … | … | … | … | … | … |
| Seafood and plant proteins | … | … | … | 5 | 0 | ≥0.8 oz/1000 kcal | … | … | … |
| Total protein foods | … | … | … | 5 | 0 | ≥2.5 oz/1000 kcal | … | … | … |

| Table 1. Differences between HEI-2005, HEI-2010, and AHEI-2010 Components and Scoring Criteria |
| --- |
|  | **HEI-2005** | **HEI-2010** | **AHEI-2010** |
|  | **Maximum Points** | **Criteria** | **Maximum Points** | **Criteria** | **Maximum Points** | **Criteria** |
| **Component** | **Score of 0** | **Maximum Score** | **Score of 0** | **Maximum Score** | **Score of 0** | **Maximum Score** |
| FATS |  |  |  |  |  |  |  |  |  |
| Fatty acids | … | … | … | 10 | (PUFAs + MUFAs) /SFAs ≤1.2) | (PUFAs + MUFAs) /SFAs ≥2.5) | … | … | … |
| *trans* Fat | … | … | … | … | … | … | 10 | ≥4% of energy | ≤0.5% of energy |
| Saturated fat | 10 | ≥15% of energy | ≤7% of energy | … | … | … | … | … | … |
| Long chain (ω-3) fats (EPA + DHA) | … | … | … | … | … | … | 10 | 0 | 250 mg/d |
| PUFAS | … | … | … | … | … | … | 10 | ≤2% of energy | ≥10% of energy |
| Oilsf | 10 | 0 | ≥12 grams/1000 kcal | … | … | … | … | … | … |
| OTHER |  |  |  |  |  |  |  |  |  |
|  Alcohol  | … | … | … | … | … | … | 10 | Women: ≥2.5 drinks/d;Men: ≥3.5 drinks/d | Women: 0.5-1.5 drinks/d;Men: 0.5-2.0 drinks/d |
| Sodium | 10 | ≥2.0 grams/1000 kcal | ≤0.7 gram/1000 kcal | 10 | ≥2.0 g/1000 kcal | ≤1.1 gram/1000 kcal | 10 | Highest decile | Lowest decile |
| Empty caloriesg | … | … | … | 20 | ≥50% of energy | ≤19% of energy | … | … | … |
| Calories from solid fat, alcohol and added sugar (SoFAAS) | 20 | ≥50% of energy | ≤20% of energy | … | … | … | … | … | … |
| Total | 100 |  |  | 100 |  |  | 110 |  |  |

Abbreviations: DHA, docosahexaenoic acid; ellipses, not applicable; EPA, eicosapentaenoic acid; MUFA, monounsaturated fatty acid; PUFA,

polyunsaturated fatty acid; SFA, saturated fatty acid.

aFor AHEI-2010, total vegetables excludes potatoes and juices.

bFor HEI-2005, legumes counted as vegetables only after meat and beans standard is met.

cFor AHEI-2010, whole grains include brown rice, popcorn, and any grain food with a carbohydrate to fiber ratio no more than 10:1.

dFor AHEI-2010, includes all milk products including fluid milk, cheese, yogurt, and fortified soy beverages

eFor AHEI-2010, 1 serving is 4 oz of unprocessed meat or 1.5 oz of processed meat.

fFor the HEI-2005, includes nonhydrogenated vegetable oils and oils in fish, nuts, and seeds.

gCalories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.

Adapted from http://appliedresearch.cancer.gov/hei/comparing.html and {{21 Wang,D.D. 2014;}}

| Table 2. Evaluation of Components of HEI and AHEI to Food Availability Constructs in Nutrition Environment Measures |
| --- |
| **Food Categories of NEMS-S** | **NEM-S Score** | **HEI-2010**a | **Max Points** | **AHEI-2010**a | **Max Points** |
| Fruit | 0 varieties = 0 pts< 5 varieties = 1 pt5-9 varieties = 2 pts10 varieties = 3 pts | Whole Fruit (not juice) | 5 | Whole Fruit (not juice) | 10 |
| Beverages (fruit juice) | YES 100% juice = 1 pt |  |  | Sugar-sweetened beverages & fruit juice | 10 |
| Vegetables | 0 varieties = 0 pts< 5 varieties = 1 pt5-9 varieties = 2 pts10 varieties = 3 pts | Total Vegetables (legumes counted as vegetables only after meat and beans standards are met) | 5 | Total Vegetables (excludes potatoes and juices) | 10 |
| Bread & Cereal | YES whole grain bread = 2 pts>2 varieties whole wheat bread = 1 pt&YES healthier cereal = 2 pts | Whole grains | 10 | Whole grains (whole grains include brown rice, popcorn, and any grain food with a carbohydrate to fiber ratio no more then 10:1). | 10 |
| Milk  | YES low-fat/skim = 2 points (pts)Proportion (lowest-fat to whole) ≥ 50% = 1 point (pt) | Milk | 10 | Milk (includes all milk products including fluid milk, cheese, yogurt, and fortified soy beverages) | 10 |
| Ground beef & Hot dogs | YES lean meat = 2 pts2-3 varieties < 10% fat = 1 pt> 3 varieties < 10% fat = 2 pts&YES fat-free available = 2 ptsLight, but not fat-free = 1 pt | Total Protein Foods | 5 | Red and/or processed meats (1 serving is 4 oz of unprocessed meat or 1.5 oz processed meat) | 10 |
| Baked chips | YES baked chips = 2 pts> 2 varieties baked chips = 1 pt | Empty calories (calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is more than 13 g/1000 kcal.) | 20 |  |  |
| Total | 0 to 30 points  | 100 points |  | 110 points |  |

Abbreviations: DHA, docosahexaenoic acid; ellipses, not applicable; EPA, eicosapentaenoic acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

aFor further information on points assignment, see Table 1

Adapted from http://www.med.upenn.edu/nems/measures.shtml and http://appliedresearch.cancer.gov/hei/comparing.html.

|  |
| --- |
| Table 3. Composite scores for healthy nutrition environments by neighborhood SESa |
|  | **NEIGHBORHOOD SES** |
| **NEMS Component** | **Score Range** | **High SES (n=44)** | **Low SES (n=41)** |
| Availability | 0-30 | 10.2 (9.2)b | 4.4 (5.7) |
| Price | -9-18 | 0.3 (2.4) | 2.1 (1.1) |
| Quality | 0-6 | 2.6 (2.5) | 1.3 (2.2) |
| Total | -9 to 54 | 13.1 (10.3) | 7.8 (7.7) |

Significance for all comparisons by store type and neighborhood SES is p<0.01.

aHigher scores indicate greater availability and better quality, and lower prices for healthful options compared to “regular” choices. SD, standard deviation; SES, socioeconomic status.

bValues represent mean (SD)

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Figure 1. Concentric circles of influence on eating behaviors.11–16 The individual level refers to biological, genetic, demographic, and learning history influences within any person. The individual level is nested within the family environment, which includes influences such as role modeling, feeding styles, provision and availability of foods, and other aspects of the home food environment. The third level, the microenvironmental level, refers to the local environment or community in which the family and home are immediately nested. This includes local schools, playgrounds, walking areas, and shopping markets that enable or impede healthful eating behaviors. Level 4 is the macroenvironmental level. This level refers to broader economic policies, laws, and industry policies that operate at the regional, state, national, and international levels. The influence of level 4 factors can be pervasive and project down to individual choices. The model recognizes the importance of both the nesting of levels within one another and reciprocal influences among levels.

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1. This appears to be an arbitrary decision made by the author. [↑](#footnote-ref-1)
2. Defined by Glanz et al as having the designated healthier option available and/or more varieties present [↑](#footnote-ref-2)
3. Primary shopper is defined as one who makes at least 75% of household food purchases, from households both with and without children in Chicago. [↑](#footnote-ref-3)
4. Grocery stores are defined as having 3 or more cash registers {{8 Glanz,K. 2007;}}. [↑](#footnote-ref-4)