A Study of the Dynamic Intersection of the Individual and the Food Environment in Three Populations

by

Nicole Marie Kasper-Cusick

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Doctoral Committee:
Professor Karen E. Peterson, Chair
Associate Professor Julie C. Lumeng
Associate Professor Brisa N. Sanchez
Professor Amy J. Schulz

Dedication

I dedicate this dissertation to my “Grandpa”, Arthur Kasper. A few months before my grandpa passed away, nine years ago, he called me one afternoon with a revelation. He’d been thinking about me and had decided that I should become a “professor”. The idea stuck with me and a couple of years later I decided that I agreed. Here I am now, Grandpa, graduating and I know you would be so proud and crying tears of joy, singing the fight song loudly and off-key. I will carry the lessons you taught me throughout “life”: to always give everything all that you have, in work, love, play, and, most importantly, in song.

*“Quotations” added in honor of my late grandmother, Mildred Kasper, whose hand-written cards were filled with love and mysteriously placed quotation marks.

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I would not be here today without the support of so many different people. I am going to list those people that have a direct influence on my dissertation here, but there are so many others that have played instrumental roles in my life. To all of you who have shaped me: thank you for your love, support, and guidance.

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Thank you to all of my committee for all of your continued help and support over the past four years: to Julie Lumeng, thank you for the opportunities you've provided through your research, for sharing with me your secret formula for writing papers, and for all of your wise sayings (while there are many ways to skin a cat, it's best not to let the perfect be the enemy of the good, so don't go down that rabbit hole!); to Brisa Sanchez for all of your guidance with statistical modeling, especially in regards to the built food environment; and to Amy Schulz for your help improving the final dissertation and for asking tough questions that I will continue to ponder well after the dissertation is submitted.

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Abstract

The food environment, which encompasses all of the external influences that affect a person's diet, has become a highly studied topic in public health. Many aspects of the food environment have been implicated in reducing diet quality, from the food available in the home, to the availability of different varieties of food outlets, to the changes in the food system on a national level. However, less attention has been paid to the interaction between the individual and his/her food environment: the ways in which the effects of food environment differ by individual characteristics and the ways in which the individual shapes the food environment to which he/she is exposed. This dissertation assesses the relationship between the individual and the food environment within 3 populations, at 3 levels of the food environment. First, we describe the creation of the Healthy Meal Index, a tool for measuring the healthfulness of meals served in the home to low-income children. We describe the characteristics of the parents and children that are associated with healthier meals. We found that parental education was positively associated with meal healthfulness and that parents served healthier meals to girls than boys. Next, we assess the individual characteristics and the food environment characteristics that are associated with choice of grocery store within a population of college students. We found that males, younger students, and minorities shopped at less expensive stores. Fruit and vegetable consumption was positively associated with shopping at more expensive stores. Distance to a stores in the two lowest priced store tertiles, but not the highest, affected store choice. Finally, we assessed the interaction between changes in the food environment with different socioeconomic characteristics on obesity prevalence in a nationally representative sample of the Colombian population. We found that obesity incidence was highest in the lowest wealth index and in urban areas between 2005 and 2010. Overall, our studies provide evidence for a dynamic relationship between individuals and the food environment, in which individual characteristics shape the food environment to which one is exposed and the degree to which the food environment shapes behavior is affected by the level of restriction an individual faces.

CHAPTER 1

Introduction

The food environment, which encompasses all of the external influences that affect a person's diet, has become a highly studied topic in public health as diet-related disease prevalence grows globally(Larson & Story, 2009). Many aspects of the food environment have been implicated in influencing diet quality, from the food available in the home, schools and other institutions, to the availability of different varieties of food outlets, to changes in the food system on a national level (Couch, Glanz, Zhou, Sallis, & Saelens, 2014; Drewnowski & Popkin, 1997; Moore, Diez Roux, Nettleton, & Jacobs, 2008). There is evidence that as a whole the food environment has a profound influence on people's diets.

The ecological model has been used as a framework for studying the food environment. The ecological model presents the individual as the center of a series of concentric circles (Figure 1.1), each which represent systems of influence on the individual (Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008). Although interaction among the levels of the ecological model is fundamental to the conceptual framework, these interactions have been largely ignored in studies of the food environment (Cobb et al., 2015; Lytle, 2009). The majority of studies in the field have treated the food environment as an exposure, examining associations with diet or obesity, with the implied direction of causation from the food environment to the individual(Cobb et al., 2015; Lytle, 2009). However, as most studies are cross-sectional, causation cannot be determined and issues of reverse causation due to self-selection are not often considered (Lytle, 2009). Gaining an understanding of the ways in which the individual interacts with his or her food environment is essential for determining the actual influence of the food environment on individual health. Food environment policy and interventions require this accurate and nuanced understanding in order to be maximally effective.

In this dissertation, I examine the relationships between the individual and the food environment on three different levels of the food environment: the home, the neighborhood, and the nation. In conceptualizing the interplay between individuals and their food environments, I utilize the conceptual model presented by Lytle (Figure 1.2) (Lytle, 2009). In Lytle's model, as the restriction that each individual faces increases, the greater the degree to which the environment influences food choices. Lytle differentiates between the physical food environment and social environment in her model, which are both included as levels of the total food environment in the ecological model. Restriction may come in the form of economic constraints, transportation constraints, or other factors which limit a person's ability to access food. When restriction is limited, then the environmental, individual factors, and social factors all intersect to influence food choices.

The concept of 'restriction' as described by Lytle is analogous to the absence of 'access,' a concept often used in healthcare research (Penchansky & Thomas, 1981). Access has been clearly defined in this field and this definition may offer additional clarity to the different aspects of the concept of restriction. The "5 A's of Access", first described by Penchansky and Thomas in 1981, have since become the central framework for understanding access to healthcare. Here I will describe how each of the 5 "A's" can be applied to the food environment. An important aspect of this framework is that the overall access for an individual is only as strong as the weakest of the five dimensions.

- *Availability* can be defined as the total available food for a population and the adequacy of the supply to meet the population's dietary needs and preferences.
- *Accessibility* refers to the geographical relationship between the population and the available food outlets. Accessibility is affected, on an individual level, by access to transportation to travel to the food outlets.
- *Accommodation* refers to the features of the available food outlets that accommodate the needs and preferences of an individual. For example, grocery stores' hours, wheelchair accessibility, and whether or not they have a bike rack are aspects of accommodation.
- *Affordability* can be defined by the relationship between the prices at available food outlets, relative prices between different types of foods, and the ability of an individual to pay for the desired food.
- Finally, *acceptability* is a concept that determines whether an individual will feel comfortable and be accepted within a given food outlet. It is influenced by how welcome an individual is made to feel, as well as whether he/she feels they 'fit in' at a given establishment.

When the "5 A's of Access" framework is overlaid with that presented by Lytle, treating the concepts of access and restriction as analogous, then it is clear that as access increases, so does individual choice. Moving back to the ecological model, I use the Lytle and Penchansky and Thomas frameworks to develop an understanding of the relationships between the layers of the food environment and the individual.

This dissertation assesses the relationship between the individual and the food environment within 3 populations, at 3 levels of the food environment. I examine the interaction between the individual and his/her food environment: the ways in which the effects of food environment differ by individual characteristics and the ways in which the individual shapes the food environment to which he/she is exposed. Utilizing the framework of access and restriction, I assess individual and food environment characteristics potentially indicative of restriction, such as SES, transportation, and residence proximity to food outlets, and assess whether the associations observed provide evidence for restriction of individual choice within groups. First, I describe the creation of the Healthy Meal Index, a tool for measuring the healthfulness of meals served in the home to low-income children. I assess the characteristics of the parents and children that are associated with healthier meals. Next, I assess the individual characteristics and the food environment characteristics that are associated with choice of grocery store within a population of college students. Finally, I assessed the differential association between changes in the food environment with different socioeconomic characteristics of the population in a nationally representative sample of the Colombian population.

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Figure 1.1: Ecological Framework of the Food Environment

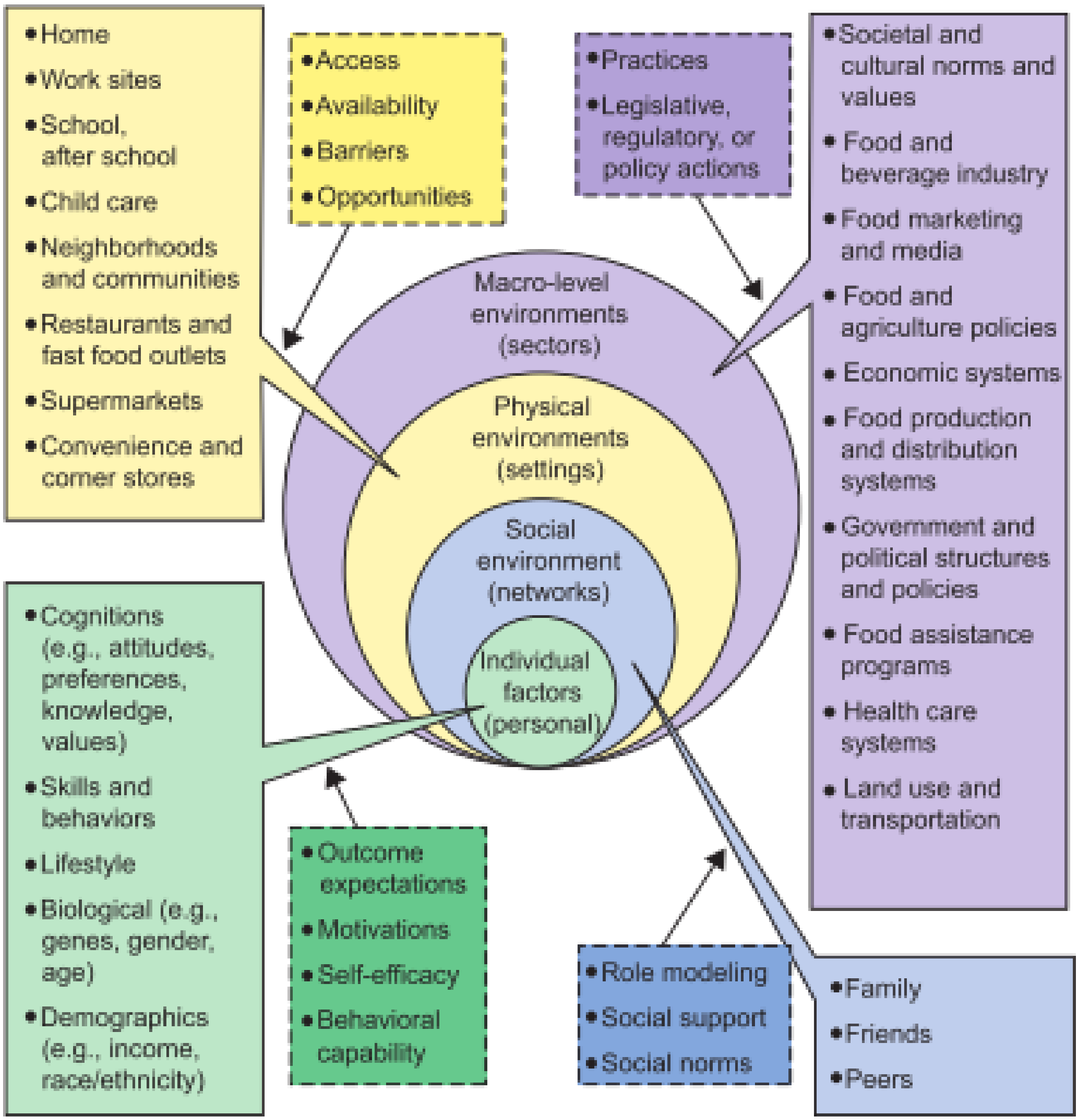

Figure 1

An ecological framework depicting the multiple influences on what people eat.

Figure taken from Story et al., 2008

Figure 1.2: The relationship bewteen the individual and the environment

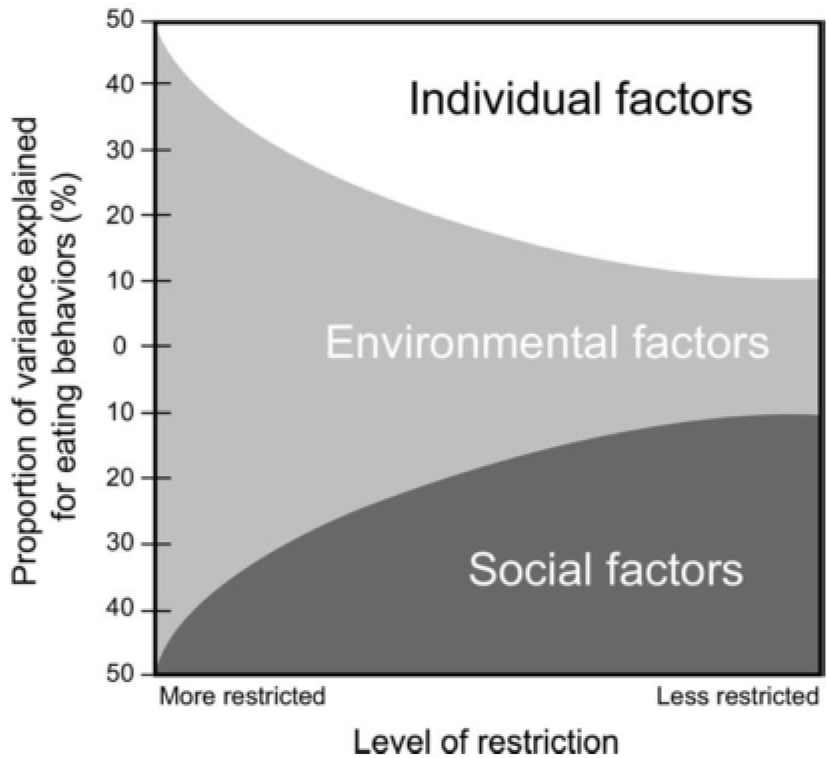

Figure 2. The relationship among individual, environmental, and social factors

Taken from Lytle, 2009

CHAPTER 2

The Healthy Meal Index: A measure of meal healthfulness in observed family dinnertimes

Nicole Kasper, MPH[1]; Cami Mandell, MPH, RD[2]; Sarah Ball, MPH, RD[1,3], Alison L. Miller, PhD[4,5]; Julie Lumeng, MD[1,4,6,]; Karen E Peterson, DSc, RD[1,4]

Affiliations

1. Department of Nutritional Sciences, University of Michigan School of Public Health Ann Arbor, MI

2. Environmental Health Sciences, University of Michigan School of Public Health, Ann Arbor, MI

3. Michigan Nutrition Obesity Research Center, University of Michigan Health System, Ann Arbor, MI

4. Center for Human Growth and Development, University of Michigan, Ann Arbor, MI

5. Health Behavior & Health Education, University of Michigan Ann Arbor, Michigan

6. Department of Pediatrics and Communicable Diseases, University of Michigan, Ann Arbor, MI

This paper is currently under review for publication in Appetite. Although this is a multi-author publication, Nicole Kasper was the primary contributor to the research described in this chapter. She wrote this manuscript and led implementation the project throughout all phases. She created the Healthy Meal Index and developed the coding protocol and oversaw the coding of all meals. She designed the validation study and conducted all analyses. She designed the analysis plan to test the associations between child and parent characteristics and HMI scores.

Abstract

Family meals have been associated with higher diet quality and reduced risk of obesity in children. Observational studies of family meals have been employed with increasing frequency, yet there is currently no tool available for measuring the healthfulness of food served during the meal. Here we present the development and validation of the Healthy Meal Index (HMI), a novel tool for scoring the healthfulness of foods served to children during a meal, as well as sociodemographic predictors of meal scores. Parents of 223 children, aged 4-8 years, self-recorded three home dinners. A research assistant obtained a list of foods available during the meal via phone call on the night of each video-recorded meal. This meal report was coded into component foods and subsequently scored based on the availability of more healthy Adequacy foods and the absence of Moderation foods, of which reduced consumption in recommended, according to pediatric dietary guidelines. Adjusted linear regression tested the association of sociodemographic characteristics with HMI scores. A validation study, conducted in a separate sample of 133 children with detailed meal data, showed that the HMI was highly correlated with servings of foods and nutrients estimated from observations conducted by research staff. In adjusted models, female children had higher HMI Moderation sores (p=0.02), but did not differ in HMI Adequacy or Total scores. Parents with more education served meals with higher HMI Adequacy (p=0.001) and Total scores (p=0.001), though no significant difference was seen in Moderation (p=0.21). The HMI provides a valuable tool for measuring the quality of meals served to children.

Keywords:

Meal Observation, Meal Assessment, Family Meals, Pediatric Feeding, Dietary Quality

Introduction

Family meals have been associated with improved diet quality, including lower intake of sugar sweetened beverages and higher intake of fruits and vegetables, as well as decreased risk of obesity in children (Jerica M Berge et al., 2015; Cason, 2006; J. a. Fulkerson, Larson, Horning, & Neumark-Sztainer, 2014; Hammons & Fiese, 2011; Larson, Neumark-Sztainer, Hannan, & Story, 2007; Ogata & Hayes, 2014; Skafida, 2013; Videon & Manning, 2003; Welsh, French, & Wall, 2011). As a result, an increasing number of practice guidelines include family mealtimes as an obesity prevention strategy and promoting family mealtimes is being tested as an intervention strategy in a randomized controlled trial (Fruh, Fulkerson, Mulekar, Kendrick, & Clanton, 2011; Fulkerson et al., 2014; Gidding et al., 2006; Ogata & Hayes, 2014).

Hypothesized mechanisms through which the family meal improves diet and weight status include increased parent-child interaction due to eating together and that meals served in the context of family mealtimes are healthier and more consistent with dietary guidelines designed to prevent obesity (Berge et al., 2014; Fiese, Hammons, & Grigsby-Toussaint, 2012; Fruh et al., 2011; Fulkerson et al., 2014; Skafida, 2013; Welsh et al., 2011). A few prior studies have found that increased parental engagement and positive interaction during the meal are associated with healthy weight status and that reported family cohesion partially mediates the relationship between family meals and diet (Berge et al., 2014; Fiese et al., 2012; Welsh et al., 2011). One survey found that families who reported placing more emphasis on family meals also reported serving healthier foods more frequently (Neumark-Sztainer et al., 2014).

A growing number of studies have focused on indexing the contextual features of the family mealtime. In particular, there has been increasing enthusiasm for employing videotaped or real time observations of family mealtimes (Berge et al., 2014; Bergmeier, Skouteris, & Hetherington, 2015; Fiese et al., 2012; Hughes et al., 2007; Hughes, Power, Orlet Fisher, Mueller, & Nicklas, 2005; Kong et al., 2013) Observed mealtime interactions provide unique information regarding the family feeding environment, particularly since behaviors observed during mealtime have been reported to have low correlation with maternal self-report of feeding practices (Bergmeier et al., 2015). The creation of universal coding systems of feeding behaviors for observational meal studies has been identified as a priority for this field of research (Hughes et al., 2013).

While a number of methods have been employed to index maternal feeding behaviors and general family interaction patterns during observed family mealtimes (Bergmeier et al., 2015), we have been unable to identify any studies that have attempted to measure the healthfulness of foods served during these mealtimes. This methodological constraint has limited the ability to comprehensively characterize the family mealtime context. Existing healthfulness measures focus on children's dietary intake, or foods actually consumed (Chiuve et al., 2012; George et al., 2014; Guenther et al., 2013; Guenther, Reedy, Krebs-smith, Reeve, & Basiotis, 2007; Marshall, Burrows, & Collins, 2014; Shanthy, Lino, Gerrior, & Peter, 1998). Characterization of the family mealtime, however, requires an index of the healthfulness of foods served during one meal. Furthermore, characterizing foods served to children is especially pertinent as current pediatric feeding guidelines recommend serving a variety of healthy foods, based on the US dietary guidelines, and allowing children to make decisions about what and how much to eat (Hetherington, Cecil, Jackson, & Schwartz, 2011; Hurley, Cross, & Hughes, 2011; Ogata & Hayes, 2014; Rhee, 2008; Vereecken, Haerens, De Bourdeaudhuij, & Maes, 2010).

This paper therefore addresses three objectives. Our first objective was to develop the

Healthy Meal Index (HMI), a method to quantify the healthfulness of foods served during a meal. Our second objective was to validate the HMI as an instrument. Our final objective was to examine the association of sociodemographic characteristics with HMI scores in a naturalistic setting.

Materials and Methods

Participants and Recruitment

Primary Sample

The primary study population comprised 301 parent-child dyads who had participated in a previous study investigating associations between stress and eating in children. About 2-4 years after the original study, primary caregivers were invited to participate in this follow-up study, which was described as seeking to understand the different ways that mothers feed children. The study included a multi-method data collection to characterize maternal feeding. This report describes features of the observed family mealtime. The original study included a total of 380 children ages 3 to 4 years recruited from Head Start programs (free, federally-subsidized preschool programs for low-income children) in Southeastern Michigan. Inclusion criteria were that the caregiver had less than a four-year college degree and was fluent in English; and that the child was born at $\geq$ 35 weeks gestation without significant complications; did not have food allergies, serious medical problems, or any form of disordered eating; and was not in foster care. Child sex, date of birth, parental race/ethnicity and parental education were collected at enrollment in the original study.

Validation Sample

We conducted a separate validation study of the HMI, utilizing meal data collected during home meal observations in a separate study that included 137 low-income children, aged 33 months (Mean(SD): 33.5(0.7)). The study was focused on child eating behavior and inclusion criteria were similar to the primary study sample. Children were recruited from Women Infants and Children (WIC) clinics and Early Head Start, programs that serve low-income families. None of the children enrolled in the primary research study that is the focus of this report were enrolled in the validation study, though some were their siblings.

Home Mealtime Observation Protocol

Primary Study Protocol

During recruitment by telephone, the primary caregiver was told, "Part of this research study is to better understand how families eat meals at home. We will loan you a video camera and ask you to tape your child's dinnertime on 3 weeknights [defined as Monday, Tuesday, Wednesday, or Thursday]. You do not need to do anything special for these dinners. We just want to understand what a typical dinner is like in different families." The parent was then asked to videotape dinners occurring in a context such that the primary caregiving parent was home and awake (as opposed to sleeping due to working an overnight shift), that the meal occurred at home (as opposed to somewhere else, like a relative's house), and that the meal was prepared by the primary caregiving parent (even when preparation is defined as picking up "take out"). If a language besides English was spoken in the home, we requested that they speak only English during the videotaped meal. Following the dinnertime meal, on the same night, parents received a telephone call from a trained interviewer. The parent was asked to, "List all the foods that were available to the child at the meal. Please provide as much detail as possible and include condiments and drinks." In order to reduce respondent burden and increase the likelihood of response, the interviewer did not ask for details about food preparation or ingredients. Participants were compensated $10 for each dinnertime meal recording they attempted.

Reliability of Meal Reports

The list of foods in the meal report was compared to the foods available on the videotaped meal for 100 meals in order to examine the completeness of the meal reports. Most (73%) of the reports of items served at the meal matched the foods observed on the videotapes, excluding condiments. Of those that did not match exactly, 20% of parents' verbal reports did not include items observed to be served on the video (omissions), while 5% of parents' verbal reports included items not observed on the video (additions); and in 2% of the videos the content of the meals could not be assessed due to framing of the video image.

Validation Study Protocol

The protocol for the study that provided the data for the validation required that a research assistant visit the home of participants to conduct behavioral assessments over 5 days. On the day of the final home visit, the parent (usually the mother) was asked to serve the child a typical meal and the research assistant recorded, in detail, the type and quantity of each food that was served to the child, including preparation methods and brands, based on visual observation. The meal was scheduled and served at a time and place when and where the child typically ate. Meals were video-recorded and children were allowed to eat to satiety. For the purpose of this study, the meal report was based on the list of foods recorded by the research assistant.

Meal Report Coding

Each meal report from the primary study and the validation study was coded into food group categories by trained coders (see coding instructions and form in Appendix A). Food categories were determined by the food groupings on ChooseMyPlate.gov, in accordance with the current US Dietary Guidelines for Americans (U.S. Department of Agriculture & U.S. Department of Health and Human Services, 2010). The presence or absence of each food group, sweets and desserts, and beverages was recorded and subsequently, the details about the type of food, as shown in Table 2.1. A list of potential mixed dishes (e.g., tacos, burgers, spaghetti) based on the Myplate Mixed Dish list, designated how each mixed dish should be coded, unless otherwise specified in the meal report. When a mixed dish was encountered that was not on the MyPlate Mixed Dish list, research was conducted to determine the common ingredients used in the dish and it was added to the Mixed Dish list to ensure that all meals containing a particular mixed dish were coded consistently. Condiments and preparation method, other than whether a potato or meat was deep fried, were not coded, as this information was not uniformly available in the meal reports.

Reliability of Coded Meals

Thirty meals were coded by four experts with graduate training in nutrition in order to test and refine the coding system. Any discrepancies were discussed and adjustments to the coding system or clarification in the coding instructions were made as needed until all expert coders agreed on the coding for these 30 meals. The relative scores of the 30 meals were assessed qualitatively by the nutrition experts in order to ensure that meals ranked appropriately in terms of healthfulness. These results were used as the standard against which subsequent coders' reliability was assessed. Coders were required to achieve a Kappa of greater than 0.7 for each item (listed in Table 2.1) for all of the 30 meals prior to beginning coding the remainder of the meals. Coding was completed within weeks of coders' reliability testing, therefore retesting of reliability was not conducted.

Meal Report Scoring- The Healthy Meal Index

We consulted current dietary guidelines and recommendations for children to construct the scoring criteria for the Healthy Meal Index (HMI), including MyPlate, the Dietary Guidelines for Americans, and the American Heart Association (AHA) Dietary Guidelines (Gidding et al., 2006; U.S. Department of Agriculture & U.S. Department of Health and Human Servies, 2010) to ensure the content validity of the HMI as a measure of healthfulness. These guidelines recommend increasing consumption of fruits, vegetables, especially dark green, red, and orange vegetables and legumes, whole grains, lean protein, low-fat dairy (or increasing calcium consumption), and foods high in healthy fats, such as fish. In addition, decreasing consumption of saturated and trans fat, fried foods, added sugars, sodium, and sugar sweetened beverages is recommended.

The Healthy Meal Index (HMI) scoring was adapted from the Healthy Eating Index and the Alternative Healthy Eating Index, in accordance with the current dietary recommendations for young children (Chiuve et al., 2012; Gidding et al., 2006; Guenther et al., 2014; Nicklas & Hayes, 2008; U.S. Department of Agriculture & U.S. Department of Health and Human Services, 2010). Similar to these existing dietary quality indices, the HMI has 2 components: the HMI Adequacy Score (based on the presence of foods that are recommended for a healthy diet) and the HMI Moderation score (based on the absence of foods recommended to be consumed in moderation), which are summed to obtain the HMI Total score (higher scores indicate healthier meals). The scale for scores for each item was chosen in order to maintain consistency with the scoring systems utilized in the HEI and AHEI. Scoring details are provided in Table 2.2. SAS

Version 9.3 was used to score the meals, based on the foods that were coded in the verbal meal reports. An individual food could fall into more than one category and would receive the appropriate points for each of the relevant categories. For example, fast food fried chicken would be categorized as a protein, an added or saturated fat, and a convenience food. The HMI Adequacy score has a potential range of 0 to 65, the HMI Moderation score has a potential range of 0 to 40, and the HMI Total score has a potential range of 0 to 105. Higher scores indicate better dietary quality. For this analysis, we calculated the mean HMI Adequacy, HMI Moderation, and HMI Total scores across the 3 meals, which were used as the outcome variables of interest.

Data Analysis

Primary Study

For the primary study, we limited the sample to only those participants who responded to all 3 telephone calls reporting what was served for dinner (n =233). The sample that provided all 3 meal reports (n = 233) differed from the sample who did not (n = 68) with regard to maternal race/ethnicity, with those included in the sample more likely to be White/non-Hispanic (72% versus 53% not included in the sample, p=0.004) and maternal age, with those in the sample being older (31.6 vs 28.9 years, p=0.001). There was no difference with regard to maternal education or child age.

To test the hypothesis that HMI scores varied by demographic characteristics of the parent and child, we performed unadjusted bivariate associations of demographic characteristics- child age, child gender, parental race, and parental education- with HMI Adequacy, HMI Moderation, and HMI Total Scores. We then conducted adjusted linear regression models including all covariates simultaneously to test the association of these covariates with each of the 3 HMI scores. All analyses were conducted in SAS (Version 9.3, 2011, SAS Institute Inc.).

Validation Study

For the validation study, a trained research assistant entered all food details and quantities into the Nutrition Data System for Research (NDSR). NDSR provided overall food group and nutrient data for each meal. We limited the sample to the 133 children who had been served a full meal (either lunch or dinner), excluding 4 children who were served a snack, breakfast, or unknown meal. We assessed the distribution and spread of the Adequacy, Moderation, and Total scores with univariate statistics, including measurement of skewness and kurtosis. We assessed content validity by comparing the HMI component scores to the total quantity of each food group or nutrient that the score was designed to measure and to the total caloric content of the meal using Spearman correlations. In addition, we conducted Principal Component Analysis (PCA) of the HMI component scores to determine whether the HMI captured more than one dimension and obtained the Cronbach's alpha for scored components of the Adequacy, Moderation, and Total Scores in order to measure the internal consistency of the scores. All of the statistical analyses for the validation study were conducted in SPSS (Version 22, IBM Corp).

Results

In the validation study, the Adequacy Moderation, and Total meal scores demonstrated normal distributions with the following characteristics (Mean(SD), skewness, kurtosis): Adequacy: 34.5(11.7), -0.17, -0.28; Moderation: 22.1(10.6), 0.07, -0.82; and Total: 56.6(17.0), 0.19, -0.42. Each of the HMI component scores was highly correlated with the total quantity of the food group or nutrient it represented; absolute values for correlation coefficients ranged from

0.433 to 0.909, as shown in Table 2.3. The negative correlations reported for the Moderation component scores are the direction expected, as these scores are based on the absence of the respective foods. None of the HMI component scores were highly correlated with total caloric content of the meal measured by NDSR; absolute values for correlation coefficients ranged from 0.00 to 0.277, as shown in Table 2.3. The Principal Component Analysis revealed 5 distinct factors with eigenvalues greater than 1.0. The Cronbach's alpha scores for the components that constructed each score were 0.395 for Adequacy, 0.402 for Moderation, and 0.364 for Total.

In the primary sample of 233 parent-child dyads who self-recorded a home dinner, the number of families who served each of the components of the HMI out of the 3 recorded meals is shown in Table 2.4. The majority of meals contained a protein (76.4%), vegetable (56.2%), grain (54.5%) and/or a food high in added or saturated fats (52.4%). Fruits, whole grains, and foods high in healthy fats were rarely served; 64.4%, 86.3%, 82.0% of families did not serve them in any of the three meals, respectively. Most families served vegetables of higher quality (red/orange, dark green, or legumes), more than one vegetable, dairy, processed foods, SSB or diet drinks, and desserts or sweets in one or two, but not all three of the meals.

The sample demographics and unadjusted bivariate associations with mean HMI scores are shown in Table 2.5. The mean HMI Adequacy score was 35.0 (SD: 7.5; range 13.3 to 58.3); mean HMI Moderation score was 22.7 (SD: 6.2; range 6.7 to 40.0); and the mean HMI Total score was 57.8 (SD: 10.1; range 30.0 to 86.7). Meals served to female children were higher in HMI Moderation ($p = .03$). There were no significant associations of child age or parental race/ethnicity with any of the 3 HMI scores. Higher parental education was associated with higher HMI Adequacy ($p=0.0005$) and HMI Total ($p=0.0009$) scores.

The three adjusted linear regression models including all covariates simultaneously are shown in Table 2.6. In adjusted models, we found no difference in HMI scores by age or parental race. Female children had higher HMI Moderation sores (β(SE)= 1.84 (0.82); p=0.02) and Total scores (β(SE)=2.5(1.3); p=0.05), but did not differ in HMI Adequacy. Parents with some education past high school served meals with higher mean HMI Adequacy (β(SE)= 3.42 (0.97); p=0.001) and Total scores (β(SE)= 4.43 (1.30); p=0.001), though no significant difference was seen in Moderation(β(SE)= 1.02 (0.82); p=0.21).

Discussion

This study makes several new contributions to the literature. First, the HMI is a tool that may be used by other researchers interested in measuring the healthfulness of meals served at family mealtimes. The HMI is based on existing evidence and guidelines for defining a healthy diet in children. In addition, the HMI coding was easily applied with reliability following limited training and was shown to be a valid measure of meal healthfulness. We found that families served certain food groups more often than others, with high reports of protein, vegetables, and grains, and low reported fruit, whole grain, and foods high in healthy fats. Next, we examined how the measures of healthfulness derived using this tool are linked with demographic characteristics. We found that higher maternal education was associated with healthier meals served in terms of Adequacy, but not Moderation scores and that female children were served meals with higher Moderation scores.

We utilized several methods in order to test the validity and reliability of the HMI. First, in the construction of the HMI, we consulted several pediatric dietary guidelines and current dietary healthfulness indices, in order to ensure the content validity of the HMI as a measure.

Additionally, the content validity of the HMI was confirmed by measuring the Spearman correlation coefficients between the HMI component scores and total quantity of relevant foods and nutrients measured by NDSR in the validation study. While the majority of components had very high correlations with measured servings, relatively low correlations were found for Total Grains and for Convenience Foods. The low correlation for Convenience Foods can be explained because we did not have an equivalent measure available from NDSR and thus chose sodium as a proxy measure. We chose sodium as a proxy due to the high sodium content of convenience foods, however there are many other contributors to the sodium content of meals than those foods classified into Convenience Foods. The low correlation found for Total Grains is likely due to a high variation in total grain quantity between meals that contained grain. The correlations between each component score and the total caloric content of the meal were low, demonstrating that the HMI is able to measure quality of meals, independent of quantity. There were 5 factors identified by the PCA, demonstrating that the HMI measures more than one construct. While the Cronbach's alpha scores, measuring internal consistency, were low for each of the scores, the different components are each intended to measure different constructs of the meal and thus this result is not unexpected. Nutrition experts coded and scored 30 meals, which were used to qualitatively assess the construct validity of the HMI as a method for ranking meals in terms of healthfulness and also as a method for ensuring inter-rater reliability of the coders. Finally, we tested the reliability of the meal reports by comparing the content of the meal reports to the content of the meals in 100 videotapes and found the contents to match exactly in 73% of the meals. We surmised that in some of the videos with additional foods not reported, these foods were not made available to the children.

A useful element of the HMI is that it differentiates between Adequacy and Moderation foods. We found different associations between demographic variables and food type that would not have been observed by characterizing only the overall meal healthfulness. This demonstrates that parental decision-making about providing different types of foods may differ and that different factors may play a role in predicting each. Furthermore, when examining each component of the HMI, we found that certain healthful foods, such as protein, vegetables, and grains were served with high frequency. However, within each of these food groups, families were more likely to serve less healthy options; families served added and saturated fats at the majority of meals, yet rarely served healthy fats and almost never served whole grains. While families may be meeting basic guidelines about overall food groups, they also serve moderation foods frequently and miss opportunities to serve healthier varieties of foods. This may be due, in part, to the characteristics of our sample of low-income families who face economic restrictions on dietary choices, as well as constraints imposed by government food assistance programs.

The observation that greater parental education was associated with higher HMI scores is consistent with prior literature, which has consistently found parental education to be associated with higher diet quality(Crawford et al., 1995; Rasmussen et al., 2006; Xie, Gilliland, Li, & Rockett, 2003). The association between parental education and HMI scores should be further investigated in other studies as the healthfulness of meals served may be an important mediator of the association between lower parental education and lower quality dietary intake among their children. In addition, future analysis should assess whether income mediates the relationship of parental education with HMI scores.

The observation that parents serve healthier meals to girls is notable, and may reflect greater restriction of highly palatable foods among daughters as compared to sons. Previous research has found that girls have higher diet quality than boys (Lorson, Melgar-Quinonez, &

Taylor, 2009; Rasmussen et al., 2006; Torres, Santos, Orraca, Elias, & Palacios, 2014; Xie et al., 2003), and that they have a greater preference for healthier foods (Granner et al., 2004; Robinson & Thomas, 2004). Child gender has also been previously shown to be associated with parental feeding behavior (Fisher & Birch, 1999). In one experimental study overweight mothers served meals to boys that contained a higher content of food characterized as 'unhealthy' than in meals served to girls (Bouhlal, McBride, Ward, & Persky, 2015). Although we only saw differences in Moderation HMI Scores and not in Adequacy, it is possible that the drivers of Adequacy HMI scores may differ by child sex. For example, females may have been served vegetables more frequently than males, but if males were served dairy more frequently, these differences could not be captured in the HMI Adequacy scores.

While we did not find any associations of race/ethnicity with HMI scores, previous literature on associations between race and diet quality in children has been mixed (Crawford et al., 1995; de Hoog et al., 2014; Erinosho et al., 2012; Kamphuis et al., 2006; Xie et al., 2003). This may indicate that differences in diet quality by race/ethnicity are driven by other factors than the healthfulness of meals served in the home. Furthermore, as our study population was restricted to low income families attending Head Start programs, it is possible that some of the previous studies had unmeasured confounding by income (Kamphuis et al., 2006).

We did not find any association of child age with HMI scores; however it should be noted that the children within the study fell within a narrow age range. Previous studies of US children have shown that consumption of milk, fruits, and vegetables decrease with age (Kamphuis et al., 2006; Lytle, Seifert, Greenstein, & McGovern, 2000). It is possible that overall dietary changes that occur throughout childhood are driven by changes in the school food environment and exposure to more foods outside the home as children age.

Strengths and Limitations

Understanding the family mealtime has been limited previously because there has not been a tool to measure the healthfulness of the foods served to children during these meals. The HMI provides an easy to use tool for assessing the dietary quality of meals served to young children and has potential for adaptation to a wide variety of settings. Several assumptions were required in the coding and scoring of the meal reports. In general, all foods needed to be classified into groups and so the variation within the groups was not accounted for in the scoring. Portion sizes were not assessed, although these have been shown to affect total intake in children by age five (Rolls, Engell, & Birch, 2000). The nature of using self-reported data on the foods served at the meals carries the limitation of recall or reporting bias by the mothers. Nevertheless, we found that 73% of meal reports matched the foods served in the videotapes in a subsample reliability assessment.

The use of videotaped meals to measure mealtime interactions in the home may provide a more accurate representation of behavior than parent self-reported feeding behavior, laboratory observations, or in-person home observations. However, there is still the potential that parents may have adjusted the foods served to children or their behavior due to the knowledge of being observed.

The validation of the HMI was an additional strength of our study. The validation study utilized NDSR, a widely accepted and utilized software program for nutrient analysis in research settings. However, because it accounts for ingredient choices, brands, and preparation methods, NDSR requires detailed food data which are not available in self-recorded home meal observations; therefore we utilized meal data from another meal observation study in which a research assistant was present to record all details about the foods available. Given the different study population and meal observation methods, there may be different correlations between HMI scores and the quantity of relevant foods and nutrients in the primary study, which we were unable to measure.

Conclusions

We have provided a novel tool for child feeding research to measure meal healthfulness in a natural setting. We found that child sex and parental education were associated with HMI scores. Future research should examine the effects of the healthfulness of meals served during family mealtimes on children's dietary quality and risk of obesity in longitudinal studies.

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Table 2.1: Details coded for each Meal Report

Category	Details
Fruits	• Number available
Vegetables	• Number available • Type: Potato (not potato chips), Dark green vegetable, Red or orange vegetable, Avocado, Legume, or Other • Potato Preparation: Fried, Mashed, Not fried or mashed, or Not specified
Grains	• Type: Whole, Refined, or Not specified
Protein	• Type: Poultry, Beef/Pork, Egg, Fish/Shellfish, Meat substitute, Nuts and seeds, or Not specified • Preparation: Deep fried (Includes chicken tenders/strips/nuggets/fries) or not
Dairy (& alternatives)	• Type: Milk, Cheese, Cottage Cheese, Cream sauce/soup, Yogurt, Frozen Yogurt, Pudding, or Ice Cream • Milk Type: Skim/low-fat(1%), 2%, Whole, Flavored, Soy, or Not specified
Sweets and Desserts (Non-dairy)	• If available
Beverages (Non-dairy)	• Type: Sugar Sweetened Beverage, Diet beverages, 100% Juice, Water, or Coffee/ Hot Tea
Other	• Main Dish Preparation: fast food/pre-packaged/highly processed or not • Not otherwise specified high fat food availability (includes fried salty snacks, pot pie, etc.)

Table 2.2: Scoring criteria for Healthy Meal Index

HMI components	Awarded Score[1] 0	5	10	Definition
Adequacy Score				
Fruit	N		Y	Fruit, excluding juice
Vegetables	N		Y	Vegetables, excluding fried potatoes
Vegetable Quality	N	Y		Dark Green/Red/Orange Vegetables & Legumes
Vegetable Variety	N	Y		≥2 types of vegetables
Grains	N	Y		Any whole or refined grain, excludes fried/salty snacks
Whole Grains	N	Y		Any whole grain, excludes fried/salty snacks
Dairy	N		Y	Dairy or dairy substitutes
Protein	N		Y	Meat, nuts, legumes, eggs, meat substitutes
Healthy Fats	N	Y		Fish, nuts, avocados
Moderation Score				
Convenience Foods	Y		N	Take-out, fast food, prepackaged, and processed
SSB or Diet Drinks	Y		N	Drinks with added sugar, diet drinks, flavored milk
Added & Saturated Fats	Y		N	Fried foods, beef, pork
Desserts & Sweets	Y		N	Foods with high added sugar

1. Y indicates the score awarded if the food was available at the meal and N indicates the score awarded if the food was unavailable

Table 2.3: Correlations between the HMI component scores and the total measured servings of foods or nutrients in the validation sample

HMI Component Score	Validation Quantity from NDSR	Correlation with Validation Quantity[1]	Correlation with Total Calories[2]
Fruit	Total servings of whole fruit	.909**	-.173*
Vegetables	Total servings of vegetables (excludes fried potatoes)	.849**	-0.047
Vegetable Quality	Total servings of dark green, red/orange vegetables, legumes	.866**	0.00
Vegetable Variety	Total servings of vegetables (excludes fried potatoes)	.600**	-0.066
Grains	Total servings of grains	.460**	0.16
Whole Grains	Total servings of whole grains	.647**	-0.021
Dairy	Total servings of dairy	.791**	.277**
Protein	Total servings of meats, eggs, nuts, seeds, meat alternatives	.643**	-0.021
Healthy Fats	Total servings of eggs, fish, shellfish, nuts, seeds, avocado	.871**	-0.094
Convenience Foods	Sodium content of meal	-.433**	-.171*
SSB or diet drinks	Total SSB and diet drinks servings	-.674**	-.223**
Added & Saturated Fats	Total servings of high fat and fried meats, fried grains	-.615**	-.174*
Desserts & Sweets	Total servings of candies and desserts	-.744**	-0.12

1. Spearman correlation coefficients for relationship between HMI component score and validation quantity from NDSR
2. Spearman correlation coefficients for relationship between HMI component score and total kilocalorie content of meal, as measured by NDSR
** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 2.4: Frequency of families serving each food contributing to the HMI during the three recorded meals

	Number of Meals			
	0	**1**	**2**	**3**
	%	**%**	**%**	**%**
Fruit	64.4	20.2	11.2	4.3
Vegetables	2.2	9.9	31.8	56.2
Vegetable Quality	13.3	36.5	33.5	16.7
Vegetable Variety	23.6	34.3	27.9	14.2
Grains	0.4	12.0	33.1	54.5
Whole Grains	86.3	11.6	2.2	0.0
Dairy	7.7	19.7	37.3	35.2
Protein	0.9	4.7	18.0	76.4
Healthy Fats	82.0	13.3	3.4	1.3
Processed Foods	23.6	34.3	32.6	9.4
SSB or Diet Drinks	30.0	25.3	25.3	19.3
Added and Saturated Fats	3.4	11.6	32.6	52.4
Desserts and Sweets	0.0	79.8	17.2	3.0

Table 2.5: Unadjusted bivariate associations with HMI scores

	N (%)	Adequacy Score Mean (SD)	p	Moderation Score Mean (SD)	p	Total Score Mean (SD)	p
Child Age			0.9		0.2		0.3
4-5 years	121 (51.9)	35.0 (7.8)		22.2 (5.8)		57.1 (9.9)	
6-8 years	112 (48.1)	35.1 (7.3)		23.3 (6.7)		58.4 (10.3)	
Child Gender			0.6		0.03		0.08
Female	114 (48.9)	35.3 (7.9)		23.6 (6.1)		58.9 (9.8)	
Male	119 (51.1)	34.8 (7.2)		21.9 (6.3)		56.6 (10.3)	
Parental Race			0.3		0.9		0.4
Non-Hispanic white	167 (71.7)	35.4 (7.6)		22.7 (6.1)		58.1 (10.3)	
Hispanic or non-white	66 (28.3)	34.2 (7.5)		22.6 (6.6)		56.8 (9.8)	
Parental Education			<0.001		0.2		<0.001
≤ High school	107 (45.9)	33.2 (7.1)		22.2 (6.1)		55.4 (9.0)	
> High school	126 (54.1)	36.6 (7.6)		23.2 (6.4)		59.8 (10.6)	

Table 2.6: Multiple linear regression models predicting HMI Adequacy, Moderation, and Total scores

	Adequacy		Moderation		Total	
	β (SD)	**p**	**β (SD)**	**p**	**β (SD)**	**p**
Child Age (mos)	0.02 (0.06)	0.76	0.04 (0.05)	0.45	0.05 (0.1)	0.48
Child Gender:						
Female (vs. Male)	0.7 (1.0)	0.49	1.8 (0.8)	0.02	2.5 (1.3)	0.05
Parental Race:						
Non-Hispanic white (vs. not)	1.1 (1.1)	0.33	-0.03 (0.9)	0.97	1.0 (1.4)	0.48
Parental Education:						
> High school (vs. ≤ High school)	3.4 (1.0)	<0.001	1.0 (0.8)	0.21	4.4 (1.3)	<0.001

CHAPTER 3

The relationship of grocery store choice with individual and food environment characteristics

Introduction

Numerous studies have assessed the relationship between supermarket or grocery store (herein, referred to collectively as grocery store) access and the risk for obesity in a wide variety of populations, as described in a recent review article (Cobb et al., 2015). Most published articles assessing the relationship between grocery store access and body mass index (BMI) or obesity and have had null findings, though some have found a negative relationship between grocery store access and obesity(Cobb et al., 2015). The literature examining the relationships between grocery store access and diet quality is mixed (Caspi, Kawachi, Subramanian, Adamkiewicz, & Sorensen, 2012; Caspi, Sorensen, Subramanian, & Kawachi, 2012). There is, however, a consistent relationship found between socioeconomic status and neighborhood access to grocery stores and also of socioeconomic status (SES) with obesity and fruit and vegetable intake (Giskes, van Lenthe, Avendano-Pabon, & Brug, 2011; Kamphuis et al., 2006; Larson, Story, & Nelson, 2009; Powell, Slater, Mirtcheva, Bao, & Chaloupka, 2007; Wang & Beydoun, 2007). Therefore, SES may be an important confounder in studies of grocery access and diet quality or obesity.

While the majority of previous studies have been cross-sectional, the implied direction of causation is from the food environment to the health outcome (Mackenbach et al., 2014). An underlying assumption of this research is that people shop at the stores closest to their homes, and thus either distance to the closest grocery store or density of grocery stores within a specified buffer zone are the most frequent exposure variables in relation to diet quality and obesity (Cobb et al., 2015). However, recently this assumption has been called into question as studies have found that people don't necessarily shop at the closest store and often travel outside of the buffer zone distances to the grocery store (Alkon et al., 2013; Drewnowski, Aggarwal, Hurvitz, Monsivais, & Moudon, 2012). A new wave of research on BMI and obesity is starting to examine the store of choice as the exposure and has found negative associations between store price and BMI or obesity (Drewnowski et al., 2012; Inagami, Cohen, Finch, & Asch, 2006). However, these studies maintain the same implied causal pathway from grocery store exposure to BMI and obesity (Drewnowski et al., 2012; Inagami et al., 2006).

A review of challenges and methodological issues in food environment studies, conducted by Lytle, found that one of the largest problems with research in the field is that most studies do not account for self-selection bias (Lytle, 2009). Lytle argues that we need to start 'putting the individual back into the equation'(Lytle, 2009, pS142). That is, not assuming that individuals are passive recipients of the environment but taking into consideration the role that individual choice plays in exposure to certain food environments. In a commentary, Cummins calls for better conceptual models of the relationship between the individual and the food environment in order to understand "how 'environment' gets into the 'body'"(Cummins, 2007). An understanding of the interaction of contextual factors, both on an individual and food environment level, which influence grocery store choice is critical to understanding how grocery store access and individual characteristics influence diet quality and obesity.

The literature in the field of business presents an alternative frame for the relationship between the individual and the food environment. In this field, a more dynamic perspective is taken - grocery store choice is seen as a product of the individual level characteristics and preferences and the characteristics of the stores, including price, distance, and quality (Carpenter & Moore, 2006; Jacobs, Van Der Merwe, Lombard, & Kruger, 2010; Mortimer & Clarke, 2011). Researchers in public health can benefit from the more nuanced perspective of the potentially dynamic relationship between the individual and the grocery store choice.

Current research on the food environment is largely driven by an ecological framework, which accounts for the influence of the environment on individual choices related to diet and obesity, but the dynamic interaction between the individual and environment that underlies the model is often left out of studies of the food environment (Lytle, 2009; Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008). In her review, Lytle presents a model of the association between individual choice and restriction which provides a framework for understanding the interaction between the individual and the food environment(Lytle, 2009). For every person, decisions are based on both the environment and individual preference; however the degree to which each of these realms influence choice is based on the level of restriction that the individual faces. When restriction is high, the level of individual choice is limited and choices are dictated by the environment that the individual faces. However, as restriction decreases, individual choice increases and individuals are free to make decisions based on their own preferences. Restriction is influenced by individual characteristics, such as SES and transportation, as well as characteristics of the food environment, such as distance to and prices of the grocery stores.

Previous studies of grocery store access have primarily considered distance, and until recently, less attention has been paid to other restrictive factors, such as price, transportation, and SES (Dubowitz et al., 2014; Zenk et al., 2013).

In this study, we sought to understand whether individual level and food environment level factors that influence individual restriction are associated with choice of grocery store in a population of college students in a large Midwestern public university. First, we assessed whether individual level variables, including sociodemographic characteristics, car transportation to the grocery store, food insecurity, and fruit and vegetable intake were associated with the price of the store where the student shopped. Next we examined whether food environment characteristics, including distance to different priced grocery stores, were associated with choice of grocery store.

Methods

Participants

We conducted a campus-wide survey on health in the Winter 2015 semester in a large Midwestern public university. The Office of the Registrar (RO) provided a list of 2,000 randomly selected students enrolled in Winter 2015 term courses, including students at all academic levels and colleges in the sampling frame. All students had an equal probability of selection. The selected students were sent an email inviting them to participate in a 5-10 minute survey on campus life and to be entered into a drawing to receive 1 of 20 $50 cash gift cards. Students were given the option to either follow a link to the survey or to opt out of the survey and future communication. Four reminder emails were sent, every five to ten days, to students who had not completed the survey or had not opted out of participation. The survey was administrated online via Qualtrics (c. 2015). Informed consent was obtained for all participants on the first page of the online survey. On this page, students were asked to verify that they were over 18 years old, the only eligibility criteria employed in study recruitment. In total, 782 people completed the survey. This study was approved by the Health and Behavioral Sciences Institutional Review Board at the University of Michigan.

Sociodemographic and academic variables

All participants were asked whether they consented to allow the RO to provide demographic and academic data or if they would like to self-report this data. For the majority of students, sex, race/ethnicity, age, and degree were provided by the RO. Those opting for self-report were then directed to a series of items querying sociodemographic characteristics and degree program, prior to the rest of the survey questions. The RO additionally provided aggregate demographic data for the entire sample who was invited to participate for the purposes of survey weighting. All students pursuing doctoral degrees were grouped into one category. Students pursuing Master's degrees and other non-doctoral level graduate degrees (such as certificates) were classified as Master's students. There were 7 race/ethnicity categories provided by the RO, including White, Asian, Black, Hispanic, Native American, 2 or more, and Not indicated. We combined the categories Black, Hispanic, Native American, and 2 or more into a category deemed 'Underrepresented Minorities'. Because 14% of students did not report race/ethnicity, we maintained them in the sample as a fourth category of race, 'Undeclared'.

Food Insecurity

We used a 2-item food insecurity screener to categorize students as either food secure or food insecure, which was validated utilizing data from a previous survey in UM Students conducted by our research group.. The screener consisted of the first 2 questions of the USDA 6-item Food Security Module: “The food that I bought just didn’t last, and I didn’t have money to get more.” and “I couldn’t afford to eat balanced meals.” with the following response categories: ‘often true’, ‘sometimes true’, and ‘never true’. These 2 questions have previously been shown to be a valid measure of food insecurity within households (Hager et al., 2010). The 2-item screener had a sensitivity of 86%, specificity of 96%, positive predictive value of 94%, and negative predictive value of 90% in our validation study of 589 students with food security status classified by the USDA 6 item Food Security Module. We scored the responses to each question on a scale of 0 to 2, summed the scores, and used a cut off value of 2 points or greater to indicate food insecurity. We utilized a 30-day recall period in order to ensure the greatest likelihood of overlap between the response period, grocery store audits, and current residence.

Transportation to the grocery store

We asked the question, ‘How do you usually get to the store to buy groceries?’ and options included: ‘own vehicle’, ‘ride in someone else’s vehicle’, ‘bike’, ‘walk’, ‘bus’, ‘other’, and ‘I never go to the store to buy food’. Students selecting ‘other’ were asked to provide further detail in a text response. Each of the other responses was analyzed to determine if it fit into one of the other categories and, if so, was re-categorized as such. Students who selected ‘own vehicle’ or ‘ride in someone else’s vehicle’ were categorized as car transport to the store and all other response choices were categorized as ‘other’ (non-car) transport to the store.

Fruit and vegetable intake

We assessed fruit and vegetable (FV) intake with a 2-item survey measure, which has been validated by correlation with serum carotenoid levels (Resnicow et al., 2000). It included one question to assess fruit intake: "How many servings of fruit do you usually eat each day? A serving of fruit is equal to one medium piece, two small pieces, one cup of diced fruit, or ¾ cup of 100% fruit juice. Do NOT include fruit snacks or fruit flavored drinks." and one to assess vegetable intake: "How many servings of vegetables, NOT including fried potatoes, do you usually eat each day? A serving of vegetables is equal to half a cup of cooked vegetables or one cup of salad." The responses to these questions were summed to obtain the total FV servings per day.

Grocery Store Shopped

Students were asked "When you go to the sore to buy groceries, which store to you go to most often?" and provided a list of 5 grocery store chains in the county or the option of reporting 'other' and writing in a response. Stores were assigned to each of the students who wrote in a response that could be identified as a grocery store within the county.

Geocoded Addresses

We asked each student to report their current address, including street number, street name, and zip code. In addition, we received a list of current addresses from the RO for students consenting to have information shared. We employed a step-wise procedure for geocoding the student's addresses, in which the student-provided addresses was assumed to be the most up-to-date and accurate source of information about student residence. The RO data was used as a back-up when the student-provided address was not provided or could not be geocoded due to inadequate details. All addresses were geocoded using ArcGIS Version 10(c. 2015, ESRI).

Food Outlet Geocoding

We downloaded data on all of the verified food outlets in Washtenaw County from ReferenceUSA (c. 2015, Infogroup). In this study, grocery stores were defined stores as food outlets with a SIC code description of a supermarkets or as grocery stores that met the following criteria: 1) was a store where two or more students reported shopping and 2) stocked a full range of standard grocery items, based on the results of the grocery store audits (see below). All outlet categorizations and locations were checked manually by a research assistant. The latitude and longitude for the stores were used to geocode them in ArcGIS Version 10 (c. 2015, ESRI). One supermarket had opened within the past 6 months and was not included in the downloaded list and was added manually to our database.

Grocery Store Audits

The grocery store audits were conducted from March to May of 2015. The grocery store audits utilized a market basket survey (Appendix B) constructed from previous market basket surveys utilized in grocery store audits in other studies (Block & Kouba, 2006; Breyer & Voss-Andreae, 2013; Cohen, Andrews, & Kantor, 2002; O'Connell, Buchwald, & Duncan, 2011) A market basket survey contains a list of common grocery items that would represent a diet for an individual or household over a given time period (usually 1-2 weeks). We contacted the corresponding authors for studies that had conducted similar audits and obtained a number of market basket surveys that were used as a template for our list. The majority of these were based on the USDA Thrifty food plan list of food items(Cohen et al., 2002). We made adjustments to the list to ensure that the overall market basket conformed to US Dietary guidelines in terms of food group servings and to reflect quantities of food that would meet the total caloric intake requirements for an average college student (age 19-30) over a two week time period (US Department of Agriculture & US Department of Health and Human Services, 2010). The final list contained 48 food items. For each item, the lowest price and unit quantity for that price was recorded. Whenever possible, the unit quantity recorded was exact or close to the unit quantity listed on market basket survey. Items that had been marked down due to quality problems or nearing the expiration date were not considered when choosing the lowest price.

We conducted audits of every supermarket within the City of Ann Arbor. In addition, we conducted audits of grocery stores and other stores selling grocery items at which students had reported shopping. Although several students reported shopping at bulk warehouse stores, we did not include these in the grocery store audits, as the quantities available would not be consistent with those in the market basket survey. A group of trained research assistants conducted the audits. Most audits were conducted on the same day, which was less than one month after we began collecting survey responses. Those that were not conducted that day were conducted within approximately one month of the other audits, in order to ensure temporal comparability between the prices. In total, audits were conducted on 20 stores- 17 of which were classified as 'full-service grocery stores' because they carried at least 90% of the 48 items in the market basket survey.

Data from the hand-written market basket surveys was transferred into Microsoft Excel. Because quantities for individual items varied slightly between stores, the price for each food item was standardized to the price per unit quantity listed in the market basket survey. When an item was not available at a full service grocery store, the price for that item was imputed based on the overall average price at all stores for that item multiplied by the percent difference that the store differed from all of the other stores on overall prices.

The total price for the market basket for each of the full service grocery stores was calculated by summing all of the standardized prices. The grocery stores were then ranked and assigned a tertile, based on the price of the market baskets. Although we conducted audits in the majority of the full service grocery stores closest to the majority of students who participated in the survey, some students who lived outside of the geographic area we assessed, but within Washtenaw County. In order to retain these students in the analytic sample, we assigned market basket prices and tertiles to supermarkets in Washtenaw County that we had not audited based on the average price and tertile of the same chain stores that had been assessed.

Food Environment Variables

We calculated the distance from the students' residences to each full service grocery store for students residing in Washtenaw County, utilizing the food outlet and student address geocoded data From this, the distance to the closest full service grocery store and the closest grocery store within each price tertile was assigned. As there was a geographic clustering of grocery stores observed (with some stores even sharing a parking lot), if distance to two different tertiles was within 0.1 miles from an individual's residence, then both (or all three) of the closest tertiles were categorized as being the closest.

Choice Grocery Store Variables

The closest outlet location for the grocery store where the student reported shopping was assigned for each student.

Statistical Analysis

We weighted the survey respondents to the overall characteristics of the sample invited to participate in the survey by sex, race/ethnicity, and degree. We utilized the survey raking procedure in SPSS Version 22 (IBM Corp) to assign a survey weight to each student. This procedure applies weights and corrects them in an iterative process based on the overall percent of each weighting category until the weighted survey sample matches the overall percent inputted for each category. We limited our analyses to those students with geocoded residences in Washtenaw County who reported shopping at a full service grocery store, and had data for sex, race/ethnicity, age, food insecurity, car access, fruit and vegetable intake, and housing type.

First, we compared the characteristics of the survey respondents before and after survey weighting for all survey respondents and then for those included in the analytic sample. Second, we calculated the bivariate statistics for student characteristics with the characteristics of store choice. Third, we modeled the association of student sociodemographic characteristics (age, sex, race/ethnicity, food insecurity), transport to store, and FV intake with market basket price and price tertile of the store where the student shopped using linear regression, multinomial, and ordinal regression. Multinomial regression tested each of the tertiles as independent outcomes and ordinal regression tested the tertiles as ordered categories. Each model included all student characteristic variables. Finally, we conducted 3 separate regression models with sets of food environment characteristics as predictors- distance to any grocery, closest store tertile, and distance to each store tertile, controlling for the student characteristics. All analyses were conducted in Stata Version 12. We used the svy command to account for the survey weights in all of our analyses.

Results

The characteristics of survey respondents and the analytic sample before and after survey weighting are reported in Table 3.1 (n=773). The overall demographic characteristics of students who took the survey were similar to the overall characteristics of the sample invited to participate in the survey in terms of race and degree, but females were more likely than males to participate. In addition, the analytic sample (n=466) did not differ from all respondents. There were approximately equal proportions of females and males after weighting. 58.5% of students in the weighted analysis sample were white, 17.0% were Asian, 8.9% were unrepresented minorities, and 15.6% did not report race. 18.4% of the weighted analysis sample had experienced food insecurity within the past 30 days. 70.2% reported usually riding in a car to the grocery store. The weighted mean (SE) age of the analysis sample was 22.9 (0.2) years. The mean number (SE) of FV servings per day was 3.8 (0.1).

The average price of the market basket for Tertile 1 stores was $96.16, for Tertile 2 scores was $123.33, and for Tertile 3 stores was $167.33. Tertile 1 stores included large grocery stores (Kroger), supercenters (Meijer), and one discount grocer (Aldi). Tertile 2 stores included a range of store types, from local chains (Busch's), to department stores with a limited grocery selection (Target), to a national chain (Traders Joe's). Tertile 3 stores generally had a greater selection of organic and specialty items (Whole Foods, Hiller's, Lucky's, Plum Market, People's Food Cooperative). The average distance that students lived from a grocery store was 1.3 miles for any store, 2.2 miles for a tertile 1 store, 1.9 miles for a tertile 2 store, and 1.3 miles for a tertile 3 store.

Bivariate statistics for student characteristics and characteristics of the students' grocery store choice are reported in Table 3.2. Males, underrepresented minorities, food insecure students, and students who took a car to the grocery store were more likely to shop at stores with less expensive market baskets. The average age and mean number of FV servings increased by tertile of store.

The results of the multivariate regression models for associations between student characteristics and characteristics of their store choice are presented in Table 3.3. Each model includes all of the student characteristic variables simultaneously. Overall older students shopped at stores with market baskets that were \$0.70 more expensive per each additional year of age ($p= 0.02$) and were more likely to shop at both Tertile 2 (RR (SE)=1.08 (0.04), $p=0.02$) and Tertile 3 stores (RR (SE)=1.14 (0.05), $p=0.01$) than younger students. Males shopped at stores with price baskets \$4.98 less expensive on average than females ($p=0.01$), were significantly less likely to shop at a Tertile 3 store (RR (SE)=0.59 (0.19), $p=0.01$). Asians and underrepresented minorities shopped at stores with lower prices (β (SE)= -4.86 (2.11), $p=0.02$ for Asians; β (SE)= -6.67 (2.32), $p<0.01$ for underrepresented minorities), though there were no significant associations between race/ethnicity and tertile of store choice. Food insecurity had no statistically significant association with characteristics of store choice, though the magnitude of coefficients suggested that food insecure students tended to shop at less expensive stores. Students who used a car to get to the store shopped at stores with market basket prices \$9.10 less expensive, were less likely to shop at Tertile 3 stores (RR (SE)=0.40 (0.17), $p=0.03$), as compared to students who used other modes of transportation. There was an association between daily FV intake and shopping at Tertile 3 stores (RR (SE)= 1.36 (0.12), $p<0.01$). None of the associations observed between individual characteristics and store choice were altered in the models including the food environment variables described below (results not shown).

The associations between the food environment and characteristics of store choice, controlling for student characteristics, are presented in Table 3.4. Overall distance to the closest store was not associated with characteristics of store choice. Students who lived closest to a Tertile 1 store were less likely to shop at a Tertile 2 store (RR (SE)= 0.25 (0.13), p=0.01) and the further that students lived from a Tertile 1 store, the more likely they were to shop at a Tertile 2 store (RR (SE)= 1.63 (0.37), p=0.03), but not a Tertile 3 store. Students living closest to a Tertile 2 store were 2.8 times more likely to shop at a Tertile 2 store (p=0.01) and 2.95 times more likely to shop at a Tertile 3 store (p=0.03) than a Tertile 1 store (p,trend<0.01). The further that students lived from a Tertile 2 store, the less likely they were to shop at a Tertile 2 store (RR (SE)= 0.39, p=0.01) or a Tertile 3 store (RR (SE)= 0.46 (0.15), p=0.02). There were no associations between living closest to a Tertile 3 store and characteristics of store choice.

Discussion

This study makes several contributions to the literature. First, we demonstrated that individual level characteristics were associated with store choice. Second, we showed that distance to different tertiles of stores was associated with store choice, controlling for individual characteristics. Finally, we presented evidence for a dynamic relationship between an individual and their environment, in which individual preference, restrictive factors, and the distance and relative prices of grocery stores all play a role.

Although our analysis considered only the cost of a healthy market basket at the grocery stores, it is important to note that there were additional differences that differentiated the tertiles of store types that were likely to explain some of the relationships we found. While previous studies have found the variables we considered, cost and distance, to be primary factors influencing an individual's store choice, selection and quality are also important(Jacobs et al., 2010). For some of the relationships we found, the associations may be driven primarily by environmental influences, due to high individual restriction of choice. For others, greater individual choice may underlie the associations, in which case other aspects of the grocery stores in different tertiles may play a larger role.

We found that younger students, males, Asians, and underrepresented minorities shopped at less expensive stores, controlling for all other student characteristics. In addition, the coefficients for food insecure students indicated that they shopped at less expensive stores, though the relationships did not reach statistical significance. This may indicate a prioritization of low prices over other factors for these student groups, potentially due to greater economic restriction for minorities, food insecure students, and younger students. In addition, cultural preferences for store type have been previously proposed to be a determinant of store choice (Cummins, 2007). Studies in the business literature have also found associations of grocery store choice with race/ethnicity, sex, age, and income (Carpenter & Moore, 2006). Males (compared to females), African Americans (compared to Caucasians), younger people (compared to older), and people with lower incomes (compared to higher) were more likely to shop at supercenters than other store formats (Carpenter & Moore, 2006). Additionally, males have been shown to place higher importance on objective measures of value, such as price, than females, who place a greater value on subjective measures, such as quality and experience, when choosing a grocery store (Mortimer & Clarke, 2011).

Students who utilized a car to get to the grocery store also shopped at stores with lower prices. Previous research has shown car travel to the store to be influenced independently by the distance to store and by car ownership, with positive associations for both (Jiao, Moudon, & Drewnowski, 2011). This relationship may be bidirectional, as students lived furthest from Tertile 1 stores, on average, so a car would be the necessary form of transportation to reach these stores. It may also represent prioritization of alternative transportation in some students who therefore choose to visit stores that are closer, but more expensive. Finally, it may be due to constraints faced by students who do not have access to a car and cannot travel as far and thus have a lesser degree of choice in which grocery store at which they shop, and must therefore shop at the closer, Tertile 3, stores, as reflective in the relationship between store price and car transport to store.

Our results suggest that students preferentially shopped at Tertile 1 stores, but would shop at a Tertile 2 store instead if a Tertile 1 store was less accessible in terms of distance. However, shopping at a Tertile 3 store did not seem to have the same substitutive effect for Tertile 1 or 2 stores. Shopping at a Tertile 3 store was associated with individual level characteristics, rather than distance. The decision to shop at a Tertile 3 store may be only be possible for some students who have a lower level of economic restriction (based on the model described by Lytle) and thus experience a higher degree of personal choice. Alternatively, for some students, shopping at a Tertile 3 store may be reflective of experiencing a higher level of restriction due to limited access to transportation, as demonstrated by the relationship between using other forms of transportation to travel to the store and shopping at higher tertile stores.

We found that female students and students who ate more FV servings were more likely to shop at Tertile 3 stores. Previous research has found that women's' attitudes about food differ from that of men, in that women place higher priority on eating specific diets, 'healthy' foods, and ethical considerations (Beardsworth et al., 2002; Bellows, Alcaraz V., & Hallman, 2010), which could lead to a greater preference for stores which prioritize conscientiousness of food choices over price. The relationship between FV intake and shopping at a Tertile 3 store is likely driven by both individual choice and restriction, depending on the end of the restriction spectrum where an individual falls. For example, students with high economic restriction are more likely to be constrained to purchase foods that are cheaper per calorie than fruits and vegetables and also to shop at less expensive stores. For students with low levels of restriction, those who prioritize healthy eating may have a preference for the more expensive stores.

The framework we propose which assesses the relationship between the individuals and grocery stores should be taken into consideration by policy-makers working to increase food access in their communities. Recently, in response to large disparities in supermarket access, price of, and access to healthy foods, cities have considered policies to incentivize businesses to increase access to healthy foods. While well intentioned, it is very important for cities to carefully consider the long-term effects of such policies and whether the intervention will reach the target population, especially if the target population faces high levels of restriction. Only two previous studies in the United Kingdom have assessed the dietary impact of entry of a grocery store into a previously underserved area (Cummins, Petticrew, Higgins, Findlay, & Sparks, 2005; Wrigley, Warm, & Margetts, 2003). The results were mixed, with modest effects seen in one study and no effects seen in the other. Furthermore, it has been found that entry of a large supercenter into a community has a negative impact on existing grocers; existing grocers will be least likely to fail if they compete not on price but a on quality and convenience, which may lead to higher prices or closure in those existing stores (Seiders, Simonides, & Tigert, 2000). In contrast, interventions which increase availability of healthy foods within existing stores and comprised an individual-level component, such as education, have been successful (Gittelsohn & Lee, 2013). Our study results suggest that store price is an important factor in determining store choice. Within our study population, an intervention aimed at increasing grocery access that introduced a high priced store near students would not affect students' store choice and students with greater restrictions (younger, minorities, FI) would be less likely to shop there, but that lower a lower priced store may have a greater impact. One of the limitations of this study is that we only measured one store where the student reported 'usually' shopping. However, other studies have found that people regularly visit up to 4 different grocery stores and that people who place more value on price shop at more stores than people who place more value on other factors, such as convenience (Luceri & Latusi, 2012; Maruyama & Wu, 2014). Students may have interpreted the term 'usually' to mean either most frequently or the store where they bought the majority of their food, which could have affected the store they reported.

Another limitation of this study is that we calculated the price of each store based on the price of a healthy food basket. One of the goals of our overall study was to determine the cost of a healthy diet that adhered to the US Dietary Guidelines, which may not reflect students' actual dietary preferences. However, for this analysis, we used the market basket price of a healthy diet as a proxy for the overall prices at each store. Nonetheless, the price of the total basket is likely reflective of the overall prices at the store and we do not expect the relative prices for foods not captured in the basket to differ from the foods that we measured.

One of the strengths of the study is that it challenges the assumption made in other food environment studies that the individual is a passive recipient of the environment and instead looks at how both the individual level factors and environmental level factors influence the choice of grocery store. In addition, we incorporated objective measures of both the price of market baskets and distance in our study design by conducting grocery store audits to measure prices at each store and mapping residences and store locations in ArcGIS. We were able differentiate between stores based on their prices rather than treating all grocery stores or supermarkets as a single variable type. Because of this, we were able to demonstrate that the price of a grocery store, in combination with distance to the different priced stores, is an important factor in whether or not an individual shops at a particular store. A final strength of our survey was the sampling frame that included all enrolled students and allowed us to weight the sample to account for non-response bias.

Conclusion

Future research should carefully consideration the metrics of distance commonly utilized, as they may not capture the stores where people actually shop, and should also consider store prices and individual characteristics that influence grocery store choice. Policies aimed to increase access to grocery stores should carefully consider the store characteristics that will result in reaching the target population. We found that individual level and food environment level factors played a role in grocery store choice. Finally, we suggest future research that utilizes more dynamic modeling, such as complex systems modeling, that allows for bidirectional relationships between the individual and the food environment.

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Table 3.1: Survey respondent characteristics before and after weighting for total respondents and analysis sample

	Total Respondents			Analysis Sample		
	Unweighted		Weighted	Unweighted		Weighted
	n	%	%	n	%	%
Sex						
Female	441	57.6	47.8	279	59.9	50.4
Male	332	42.4	52.2	187	40.1	49.6
Race/Ethnicity						
White	484	62.2	59.2	295	63.3	58.5
Asian	96	12.6	15.5	60	12.9	17.0
Underrep. Minorities	85	11.1	11	42	9	8.9
Undeclared	118	14	14.3	69	14.8	15.6
Food Security- 30 days						
Secure	601	82.1	81.5	376	82.5	81.6
Insecure	130	17.9	18.5	80	17.5	18.4
Transport to Store						
Other	232	28	28.9	113	24.2	29.8
Car	551	72	71.1	353	75.8	70.2

	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Age (yrs)	23.0 (0.2)	22.9 (0.2)	23.2(0.2)	22.9 (0.2)
FV Servings/day	3.9 (0.1)	3.8 (0.1)	3.8 (0.1)	3.8 (0.1)

Table 3.2: Unadjusted student characteristics and grocery store choice

	Grocery Store Price ($)	Grocery Store Shop Price Tertile		
	Mean (SE)	T1 %	T2 %	T3 %
Sex				
Female	$113.12 (1.38)	74.6	14.4	11.0
Male	$108.7 (1.03)	84.5	10.2	5.4
Race/Ethnicity				
White	$112.25 (1.25)	77.4	14.2	8.4
Asian	$108.09 (1.61)	85.4	7.6	7.1
Underrep. Minorities	$106.94 (1.51)	86.8	9.4	3.8
Undeclared	$110.97 (2.17)	77.3	11.6	11.1
30 day Food Insecurity				
Secure	$111.72 (1.05)	77.6	13.3	9.1
Insecure	$107.57 (1.08)	88.6	7.0	4.4
Store transportation type				
Other	$116.15 (2.52)	74.4	13.4	12.2
Car	$109.18 (0.79)	81.2	12	6.9
		Mean (SE)	**Mean (SE)**	**Mean (SE)**
Age (yrs)		22.6 (0.2)	23.6 (0.5)	24.7 (0.9)
FV Servings/day		3.7 (0.1)	4.2 (0.3)	4.7 (0.3)

Table 3.3: Results of regression models of the association between student characteristics and grocery store choice, controlling for all student characteristic variables

	Store Price($)		Grocery Type				
			Tertile 2 (v. T1)		Tertile 3 (v. T1)		Trend
	β (SE)[3]	p	RR (SE)[1]	p	RR (SE)[1]	p	p[2]
Age (yrs)	0.7 (0.30)	0.02	1.08 (0.04)	0.02	1.14 (0.05)	0.01	<0.01
Male (v. female)	-4.98 (1.77)	0.01	0.59 (0.19)	0.1	0.35 (0.15)	0.01	<0.01
Asian (v. White)	-4.86 (2.11)	0.02	0.5 (0.24)	0.15	0.8 (0.49)	0.72	0.2
Underrep. Minority (v. White)	-6.67 (2.32)	<0.01	0.59 (0.34)	0.36	0.41 (0.33)	0.26	0.14
Undeclared race (v. White)	-2.8 (2.75)	0.31	0.86 (0.37)	0.72	1.46 (0.76)	0.47	0.92
Food Insecure (v. food secure)	-2.69 (1.56)	0.09	0.53 (0.23)	0.15	0.51 (0.27)	0.2	0.07
Car transport to store (v. other)	-9.10 (2.90)	<0.01	0.68 (0.24)	0.26	0.40 (0.17)	0.03	0.02
FV Servings/day	1.00 (0.56)	0.08	1.13 (0.10)	0.14	1.36 (0.12)	<0.01	<0.01

1. β coefficients for the price of the grocery store where student shops from linear regression models
2. Risk Ratios for shopping in either a Tertile 2 or Tertile 3 store, compared to a Tertile 1 store from multinomial logistic regression models
3. p-values for odds of shopping in a store with a higher tertile ranking from ordinal logistic regression models

Table 3.4: Results of regression models of the association between food environment characteristics and grocery store choice

	Store Price($)		Grocery Type				
			Tertile 2 (v. T1)		Tertile 3 (v. T1)		Trend
	β (SE)[1]	p	RR (SE)[2]	p	RR (SE)[2]	p	p[3]
Model Type 1[4]							
Distance to closest (miles)	1.26 (1.83)	0.49	0.59 (0.18)	0.09	0.74 (0.21)	0.29	0.08
Model Type 2[4]							
T1 closest	-4.14 (2.37)	0.08	0.25 (0.13)	0.01	0.61 (0.29)	0.31	0.02
T2 closest	2.63 (2.84)	0.36	2.8 (1.06)	0.01	2.95 (1.44)	0.03	<0.01
T3 closest	-1.15 (1.89)	0.54	1.17 (0.39)	0.64	1.6 (0.67)	0.26	0.32
Model Type 3[4]							
Distance to T1 (miles)	1.21 (1.08)	0.27	1.63 (0.37)	0.03	1.12 (0.31)	0.68	0.08
Distance to T2 (miles)	-0.84 (1.44)	0.56	0.39 (0.14)	0.01	0.46 (0.15)	0.02	<0.01
Distance to T3 (miles)	-2.65 (1.04)	<0.01	0.79 (0.17)	0.27	0.6 (0.16)	0.06	0.04

1. β coefficients for the price of the grocery store where student shops from linear regression models
2. Risk Ratios for shopping in either a Tertile 2 or Tertile 3 store, compared to a Tertile 1 store from multinomial logistic regression models
3. p-values for odds of shopping in a store with a higher tertile ranking from ordinal logistic regression models
4. All models control for age, race/ethnicity, 30 day food insecurity, store transportation type, and FV servings, additionally Type 1 models included the following covariate: distance to closest; Type 2 models also included: T1 closest, T2 closest, T3 closest; and Type 3 models also included: distance to T1, distance to T2, distance to T3.

CHAPTER 4

Obesity prevalence in Colombian adults is increasing fastest in lower socioeconomic status groups and urban residents: Results from two nationally representative surveys

Nicole M. Kasper[1], Oscar F. Herrán[2], Eduardo Villamor[3]

[1] Department of Environmental Health Sciences and [3] Department of Epidemiology, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, Michigan 48109-2029. [2] School of Nutrition and Dietetics, Faculty of Health, Industrial University of Santander, Carrera 32 No. 29-31, Bucaramanga, Colombia.

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Abstract

Objective: Low- and middle-income countries are experiencing rises in the prevalence of adult obesity. Whether these increases disproportionately affect vulnerable subpopulations is unclear because most previous investigations were not nationally-representative, were limited to women, or relied on self-reported anthropometric data which are subject to bias. The aim of this study was to assess changes in the prevalence of obesity from 2005 to 2010 in Colombian adults; overall, and by levels of sociodemographic characteristics.

Design: Two cross-sectional, nationally representative surveys.

Setting: Colombia.

Subjects: Men and women 18-64 years old (n=31,105 in 2005; n=81,115 in 2010)

Results: The prevalence of obesity (BMI ≥30 kg/m^2) was 13.9% in 2005 and 16.4% in 2010 (prevalence difference=2.7%; 95% confidence interval [CI]=1.9, 3.4%). In multivariable analyses, obesity was positively associated with female sex, age, wealth, and living in the Pacific or National Territories regions in each year. In 2010, obesity was also associated with living in an urban area. The change in the prevalence of obesity from 2005 to 2010 varied significantly according to wealth; 5% (95 % CI=3.3, 6.7%) among the poorest and 0% (95% CI=-1.6, 2.2%) in the wealthiest (P, test for interaction=0.007), after adjustment. Obesity rates also increased faster in older than younger people (P, test for interaction=0.01), among people from urban compared to non-urban areas (P, test for interaction=0.06), and in adults living in the Atlantic region compared to others.

Conclusions: Adult obesity prevalence has increased in Colombia and its prevalence increased greatest in the poor, in urban populations, and specific geographic regions.

Introduction

The global prevalence of obesity has been on the rise in the past couple of decades, especially in developing countries (Kelly, Yang, Chen, Reynolds, & He, 2008; Malik, Willett, & Hu, 2013b; Prentice, 2006). Between 1980 and 2008, mean body mass index (BMI) increased by 0.4 kg/m^2 per decade in men and 0.5 kg/m^2 per decade in women worldwide (Finucane et al., 2011b). These increases have been steeper in Latin America, ranging from 0.6 to 1.4 kg/m^2 per decade (Finucane et al., 2011b). In parallel with this shift in the BMI distribution, global obesity prevalence doubled and by 2008 there were an estimated 502 million obese adults in the world, including 9.8% of men and 13.8% of women (Finucane et al., 2011b). These changes are typically followed by rises in obesity-related chronic diseases, including type 2 diabetes and cardiovascular disease, which may have devastating effects on the economies and health systems of developing countries (Hossain, Kawar, & El Nahas, 2007; Prospective Studies Collaboration, 2009). Whereas the obesity epidemic in adults from the United States appears to be leveling-off(Flegal, Carroll, Kit, & Ogden, 2012), it is uncertain whether the same is true for other regions in the Americas. In Brazil, the prevalence of obesity in adults 20 years of age or older increased from 11.1% in 2002-2003 to 14.8% in 2008-2009 according to representative anthropometric surveys (Instituto Brasileiro de Geografia e Estatística - IBGE, 2004, 2010). Nevertheless, data from other countries have not been nationally-representative, have focused only on women, or have relied on self-reported anthropometric data, which is subject to bias.

Obesity is inversely associated with socioeconomic status (SES) in developed countries, yet, in poorer nations obesity is positively associated with wealth (Jones-Smith, Gordon-Larsen, Siddiqi, & Popkin, 2012; Pampel, Denney, & Krueger, 2012; Subramanian, Perkins, Ozaltin, & Smith, 2011). Survey data from women of childbearing age indicate that the prevalence of obesity grew more in the wealthiest than in the poorest groups of most low- and middle-income countries over the past two decades (Jones-Smith et al., 2012; Pampel et al., 2012; Subramanian et al., 2011). Nevertheless, in some lower income countries, rates of obesity are growing faster among adults in the lowest (compared to the highest) wealth and education groups (Fleischer, Roux, & Hubbard, 2012; Jones-Smith et al., 2012; Subramanian et al., 2011). It is hypothesized that this shift in the burden of obesity from the wealthier to the poorer may occur as countries reach a critical point in economic development (Monteiro, Moura, Conde, & Popkin, 2004a), partly as a consequence of lowered prices of unhealthy foods, unevenness in access to a healthy diet, and urbanization (Drewnowski & Popkin, 1997; Drewnowski, 2004; Haines, Siega-Riz, & Popkin, 1999; Larson, Story, & Nelson, 2009; Malik et al., 2013b; Popkin, 2003). However, few studies have examined recent changes in adult obesity within socioeconomic strata using nationally-representative data.

We examined the trends in obesity prevalence in Colombian adults from 2005 to 2010 using data from two consecutive national nutrition surveys. We estimated changes in obesity prevalence overall and by levels of sociodemographic characteristics, including sex, age, urbanicity, food security, wealth, and region.

Methods

Study Population

The Colombian National Nutrition Surveys (ENSIN) were time-series, nationally representative, cross-sectional surveys of the Colombian population conducted in 2005 and 2010 by the Colombian Institute of Family Welfare (Instituto Colombiano de Bienestar Familiar). Details on each survey have been published elsewhere (Instituto Colombiano de Bienstar Familiar, 2005, 2011). In brief, participants were selected to represent 99% of the country's population using a multistage stratified sampling scheme. All municipalities from the 32 departments in the country were grouped into strata based on similar geographic and sociodemographic characteristics. One municipality was randomly chosen from each stratum, with probability proportional to the population size. Clusters of about 10 households each were then randomly chosen from within these strata and household members were invited to participate. The 2005 survey included 17,740 households representing 1,920 clusters from 209 strata. In the 2010 survey, 50,670 households were included, representing 4,987 clusters from 258 strata.

Consent for participation in the surveys was obtained by the Colombian Institute of Family Welfare prior to enrollment. The University of Michigan Institutional Review Board determined that analyses of these anonymized data were exempt from review.

Data Sources

In both surveys, trained personnel administered questionnaires to the head of the household to obtain information on demographic characteristics, measures of food insecurity, and wealth. Anthropometric measurements were obtained for all household members by research personnel who had been trained and standardized on the use of anthropometric techniques, with the use of calibrated instruments. Height was measured with the use of a height board (Shorr Productions LCC, Olney, MD) in 2005 and a stadiometer (Diseños Flores S.R. Ltda, Bogota, Colombia) in 2010, to the nearest millimeter. Weight was measured on SECA Alpha Model 770 scales in 2005 and on SECA 872 scales in 2010, to the nearest 100 grams.

The surveys included 76,367 people in 2005 and 188,599 in 2010. For these analyses, we excluded participants <18 years of age (n=29,668 in 2005 and n=74,666 in 2010) and women who reported being pregnant or who answered 'don't know' to a question on pregnancy status (n= 1,707 in 2005 and n=1,793 in 2010). In 2005, 4,703 people aged 65 or older were excluded. In 2010, no one ≥65 years-old was included in the survey. In addition, 9,184 and 21,025 people with missing data on height or weight were excluded in 2005 and 2010, respectively. Men were more likely than women to have missing anthropometric values, especially in 2005 (Appendix C: **Table SC.1**). The final analytic sample comprised 31,105 adults aged 18 to 64 years in 2005 and 91,115 in 2010.

The outcome of interest was obesity, defined as body mass index greater than or equal to 30 kg/m^2 ("Physical status: the use and interpretation of anthropometry. Report of a WHO

Expert Committee.," 1995). The primary correlate was year of survey (2005 or 2010). In addition, we considered sociodemographic variables as correlates of obesity within each survey, including age, sex, marital status, geographical region, urbanicity, food security, and wealth. Urbanicity was categorized as living in urban settlements, in small villages or rural areas around a small town, or in rural disperse areas distant from the nearest town. Food security status was measured using a modified version of the Community Childhood Hunger Identification Project (Wehler, Scott, & Anderson, 1992)(Wehler et al., 1992) which has been previously adapted for and validated in a Colombian population (Álvarez, Estrada, Montoya, & Melgar-quiñónez, 2006). There are 12 questions addressed to the head of the household regarding food insecurity experienced within the past 30 days due to lack of money for food. Only 7 questions are asked to households without children. In 2010, additional questions were added to the survey; however, for comparability between years, we used only the questions and scale from 2005 to create a comparable measure of food security for both survey years. Response options for each question; no, seldom, sometimes, or always; were assigned codes 0, 1, 2, or 3, respectively. Codes were added through all responses and the sum was categorized into a 4 level variable: food secure (sum=0), mild food insecurity (sum=1 to 7 or 1 to 12 in households without or with children respectively), moderate food insecurity (sum=8 to 14 or 13 to 24), or severe food insecurity (sum≥15 or ≥25). Wealth was measured using an index designed for the international Demographic and Health Surveys (Rutstein & Johnson, 2004). This wealth index is constructed for each survey year from principal component analysis (PCA) of a number of household assets, including type of flooring, number of bedrooms, type of toilet, mode of transportation, etc. The distribution of these variables is first standardized for the population, and z-scores for each variable are assigned to each household. PCA is then performed using the standardized variables; the first factor identified is used to define the wealth index as a continuous variable. A higher index represents more wealth. Each person is assigned the wealth index of their household. The continuous wealth index was categorized into quintiles according to its distribution among all survey participants, accounting for the complex survey design.

Statistical Analysis

All analyses were conducted with the use of the complex survey design routines of Stata software Version 12 (Stata Corporation, College Station, TX). We estimated weighted prevalences of obesity by year and within year by categories of sociodemographic predictors. Obesity prevalences were compared by levels of each correlate with the use of Rao-Scott Chi-Square tests and tests for linear trend for nominal and ordinal predictors, respectively; accounting for the complex survey design. We estimated adjusted prevalence ratios of obesity by levels of sociodemographic predictors in each year of the survey, with the use of multivariable Poisson regression models with the log-link and robust estimates of variance. In these models, adjustment variables included sex, age, marital status, food security, wealth, urbanicity, and region of residence, categorized according to Table 1. Finally, we examined the change in obesity prevalence from 2005 to 2010 overall and by levels of sociodemographic variables by estimating adjusted prevalence differences (PD) and 95% confidence intervals (CI) in multivariable Poisson regression models. To determine whether changes in obesity prevalence from 2005 to 2010 differed significantly between levels of sociodemographic predictors, we tested cross-product (interaction) terms between year and categories of each predictor with the use of adjusted Wald tests. In supplemental analyses, we examined associations of obesity with year and sociodemographic characteristics stratified by sex.

Results

Mean BMI ± standard error (SE) in 2005 and 2010 was 25.2±0.1 kg/m^2 and 25.7±0.0 kg/m^2 respectively; the difference between the years was 0.5 kg/m^2 (95% CI=0.4, 0.6 kg/m^2). There were no major changes in the shape of the BMI distribution between the survey years overall or by sex (**Figure 4.1**). Prevalence ± SE of obesity in 2005 and 2010 was 13.9±0.3% and 16.4±0.2%, respectively. The prevalence difference (PD) was 2.7% (95% CI=1.9, 3.4 %).

In both years, the prevalence of obesity was highest in women, participants 55-64 years of age, those without food insecurity or who were at the highest quintiles of wealth index, and people living in urban areas or in the National Territories region (**Table 4.1**). Some of these associations differed between women (Appendix C: **Table SC.2**) and men (Appendix C: **Table SC.3**). For example, the positive associations of wealth index and food security with obesity in both survey years were stronger in men than women. Similarly, the higher prevalence of obesity in urban compared to rural areas in both survey years was apparent in men but not in women.

Next, we examined the associations of sociodemographic factors and prevalence of obesity in each survey year after adjusting for potential confounding (**Table 4.2**). In both years, obesity was positively associated with female sex, age, and living in the Pacific or National Territories regions. Whereas in 2005 the association of wealth with obesity followed a dose-response gradient, in 2010 the prevalence of obesity was equally higher in wealth quintiles 2 to 5 as compared to the lowest quintile. By contrast, while living in rural areas (small rural villages or disperse rural areas) was not related to the prevalence of obesity in 2005, it was associated with lower prevalence compared to urban areas in 2010.

Finally, we examined the change in the prevalence of obesity from 2005 to 2010 by estimating prevalence differences in categories of each predictor, from multivariable regression models (**Figure 4.2**). The change in the prevalence of obesity was significantly higher in persons 55-64 years of age than in younger adults (P, test for interaction with year=0.01). There was also in inverse relation between wealth and change in obesity prevalence (P, test for interaction with year=0.007). After adjustment, the prevalence difference between 2010 and 2005 in the poorest group was 5.0% (95% CI=3.3, 6.7 %) whereas there was not a significant change in the wealthiest group (PD=0.3 %; 95% CI=-1.6, 2.2 %). The change in obesity prevalence was higher in people living in an urban environment (PD=3.3%; 95% CI=2.5, 4.1%), compared to that in people living in small rural towns (PD=0.4 %; 95% CI=-1.7, 2.6%) or in disperse rural areas (PD=-0.3 %; 95% CI=-3.4, 3.3%) (P, test for interaction with year=0.06). The increase in obesity prevalence also varied significantly by region (P, test for interaction with year=0.02). The highest increase was observed in the Atlantic region (PD=3.8%; 95% CI=2.5, 5.2%), followed by the Central (PD=3.0%; 95% CI=1.8, 4.3%), Oriental (PD=3.0 %; 95% CI=1.4, 4.5%), Pacific (PD=2.2%; 95% CI=0.5, 4.0%), Bogota (PD=0.8%; 95% CI=-1.2, 2.8%), and National Territories (PD=0.4%; 95% CI=-1.6, 2.4%). When the results were stratified by sex, the differential increases in obesity prevalence by age, urbanicity, and region were more evident in women (Appendix C: **Figure SC.1**) than men (Appendix C: **Figure SC.2**). However, the greatest increase among the poorer than the wealthier remained apparent in both women and men.

Discussion

The average BMI of Colombian adults increased by 0.5 kg/m^2 between 2005 and 2010, equivalent to a rate of 1.0 kg/m^2 per decade, which is twice the mean BMI increase rate that has been noted globally, but on pace with the increase seen in the Latin American region (Finucane et al., 2011a). Obesity prevalence has increased in both adult men and women; however, this rise has not been uniform. Although obesity was positively related to wealth in both years, the fastest increments have occurred in people of the lowest SES and among those living in urban areas. Whereas obesity was most prevalent in the National Territories region in both years, the rise between the surveys was lowest in that region and highest in the Atlantic, so that regional differences seen in 2005 appeared to be leveling out by 2010.

Obesity was associated with high SES in both 2005 and 2010. In settings at early stages of the nutrition transition, a positive relation of SES with obesity might be explained by increased access to processed foods and more sedentary life-styles among the better-off. While wealth was related to obesity in each survey year, there was a strong gradient in prevalence change between survey years by wealth index. The prevalence increased by 5% in the poorest people but there was virtually no change in the wealthiest. This trend was more apparent in women than in men and could partly explain the lack of a clear correlation between obesity and wealth in 2010 among females. The shift in the burden of obesity from the richer to the poorer has been documented as countries move through economic development, and appears to affect women before men, consistent with the results of our study. It could be due to increased availability of low-cost obesogenic foodstuffs of poor nutritional quality that are consumed by the least affluent (Drewnowski & Specter, 2004). In a review of studies from 14 countries, Monteiro et. al found that the reversal of the association between obesity and SES occurs when countries have a per capita gross national product (GNP) of about US $2,500 in 2004 (approximately US $3,072 in 2013), and that this occurs at a lower GNP per capita for women than men (Monteiro, Moura, Conde, & Popkin, 2004b). This shift may be occurring in Colombia at a higher GNP level (from about US $3,281 in 2005 to US $4,895 in 2010, in 2013 US dollars) (United Nations Statistics Division, 2013). An alternative explanation for our findings may be convergence to the mean and a shift towards a diminished association between obesity and wealth. Future monitoring of obesity trends in Colombia are required to determine whether or not Colombia continues to follow the pattern observed in other countries that have undergone the Nutrition Transition. That is, an eventual shift in the burden of obesity to the poor.

We found that obesity prevalence was highest in urban areas in 2005 and 2010 and that prevalence was growing faster in urban than rural areas, when controlling for sex, age, wealth, food security, and other covariates. Decreased physical activity and increased consumption of high energy foods related to urbanization have been identified as major contributors to the rise in obesity prevalence worldwide (Malik, Willett, & Hu, 2013a). Between 2005 and 2010, imports of food products in Colombia doubled (Food and Agriculture Orgnization of the United Nations, 2013), potentially enhancing exposure to a more 'Western' diet, which has been associated with risk of obesity (Hawkes, Chopra, & Friel, 2003). An additional explanation for the greater increase in obesity among urban than rural inhabitants is that the change is mediated by improvements in SES (Neuman, Kawachi, Gortmaker, & Subramanian, 2013). This may not necessarily be the case in Colombia, where social and political unrest continued to displace a substantial number of people from rural to urban areas to engross the poorer groups in the cities during the period between surveys.

Of note, food security status was positively related to the prevalence of obesity in both survey years. Nonetheless, after adjustment for wealth and other potential confounders the association was attenuated and became non-statistically significant. The role of food security on obesity is controversial and possibly depends on a country's stage through the nutrition transition. In countries at more advanced stages, severe food insecurity has been related to increased prevalence of obesity(Kac et al., 2012; Leung, Williams, & Villamor, 2012),whereas in countries at earlier stages, it is related to underweight(Isanaka, Mora-Plazas, Lopez-Arana, Baylin, & Villamor, 2007). In our case, the attenuation of a positive relation of food security with obesity after adjustment suggests that it may have been confounded by socioeconomic status.

The geographical gradient of the recent changes in obesity prevalence is noteworthy. The highest increase was observed in the Atlantic region, followed by the Oriental, Central, and Pacific regions, with virtually no change in Bogota or the National Territories. The Atlantic region's prevalence was lowest in 2005; thus, regression to the mean could be an explanation of the greatest shift observed there. Nevertheless, causal explanations cannot be ruled out. These might include region-specific changes in food availability or physical activity patterns related to drifts in socioeconomic or environmental conditions during this period. Future research into potential explanations for the geographic variation in changes in obesity prevalence might inform potential public health interventions to prevent further increases.

A major strength of this study is that it assessed changes in prevalence of obesity using measured height and weight data from nationally representative samples of both adult men and women. Recent changes in the burden of obesity within socioeconomic strata had not been carefully characterized in this region. The majority of prior studies of obesity trends relied on data from the Demographic Health Surveys, which are limited to women of childbearing age; the World Health Organization World Health Surveys, which rely on self-reported heights and weights; or small, non-representative samples (Finucane et al., 2011a; Fleischer, Diez Roux, & Hubbard, 2012; J. Jones-Smith, Gordon-Larsen, Siddiqi, & Popkin, 2012; Martorell, Khan, Hughes, & Grummer-Strawn, 2000). One limitation of the study was that a sizeable group was excluded for lack of data on height or weight. If the probability of inclusion in the analyses was related to both survey year and BMI status, results could be affected by selection bias. Men were excluded more frequently in 2005 due to lack of anthropometric data, but it is uncertain whether the prevalence of obesity differed between participating and non-participating male subjects.

In sum, the prevalence of obesity among Colombian adults increased by about 3% between 2005 and 2010. This increase has disproportionately affected the poorest people in the country and those residing in urban areas. The implications of these changes on rates of obesity-related chronic diseases require careful surveillance. Whether similar trends exist in children is a critical next step in the research agenda. Identifying both immediate and contextual causes of the recent increases in obesity rates will allow appropriate interventions and policy to be implemented to decrease their impact.

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Table 4.1: Prevalence of obesity in Colombian adults in the National Nutrition Surveys of 2005 and 2010

	2005				2010			
	N[1]	% Obese	SE[2]	*P* value[3]	N[1]	% Obese	SE[2]	*P* value[3]
Sex				<0.0001				<0.0001
Male	12,426	9.0	0.4		39,489	11.5	0.2	
Female	18,679	17.0	0.4		51,626	20.0	0.2	
Age, years				<0.0001				<0.0001
18-24	6,818	3.8	0.3		18,959	5.6	0.2	
25-34	8,053	10.3	0.5		22,766	13.2	0.3	
35-44	7,228	16.4	0.6		20,625	18.9	0.4	
45-54	5,589	22.2	0.8		17,431	23.2	0.4	
55-64	3,417	22.2	0.9		11,334	25.2	0.5	
Marital status				<0.0001				<0.0001
Married	7,788	19.0	0.6		21,561	21.6	0.4	
Living Together	10,512	13.9	0.5		33,625	17.5	0.3	
Never Married	8,059	6.6	0.4		22,358	8.4	0.2	
Separated	3,738	15.6	0.8		11,113	17.7	0.4	
Widowed	998	25.6	2.1		2,436	28.4	1.1	
Food security				0.04				0.001
Food Secure	17,516	14.5	0.4		47,378	16.9	0.2	
Mild Food Insecurity	7,637	14.1	0.6		27,716	16.2	0.3	
Moderate Food Insecurity	3,455	12.0	0.8		12,640	15.7	0.5	
Severe Food Insecurity	1,080	13.8	1.7		3,381	14.2	0.8	
Wealth index quintile				<0.0001				<0.0001
1- Poorest	5,463	8.6	0.6		24,765	12.4	0.3	
2	8,005	13.2	0.6		21,768	17.1	0.4	
3	7,061	14.0	0.6		17,905	16.9	0.3	
4	5,936	15.8	0.7		14,275	18.0	0.4	
5- Wealthiest	4,640	16.2	0.8		12,402	17.3	0.4	
Urbanicity				<0.0001				<0.0001
Urban area	24,927	14.6	0.4		64,314	17.1	0.2	
Small rural village	3,549	12.9	0.8		16,051	15.3	0.5	
Disperse rural area	2,629	10.0	0.9		10,750	13.6	0.4	
Region				0.004				<0.0001
Atlantic	7,305	12.5	0.5		20,263	16.6	0.4	
Oriental	3,516	14.5	0.8		13,220	17.2	0.4	
Central	6,132	13.6	0.5		23,001	16.6	0.3	
Pacific	4,386	15.3	0.8		13,678	17.4	0.4	
Bogotá	1,510	13.2	1.0		5,785	14.1	0.5	
National Territories	8,256	18.3	0.8		15,168	17.8	0.5	

[1] N refers to the total sample frequency for each category. In 2005, 15 people and in 2010, 29 people had missing values for marital status and were excluded from the descriptive statistics of marital status. In 2005, 2,063 people had missing values for food insecurity and were excluded from the descriptive statistics of food insecurity.

[2] Percent obesity (BMI≥30 kg/m^2) and standard error are weighted to represent the Colombian population.

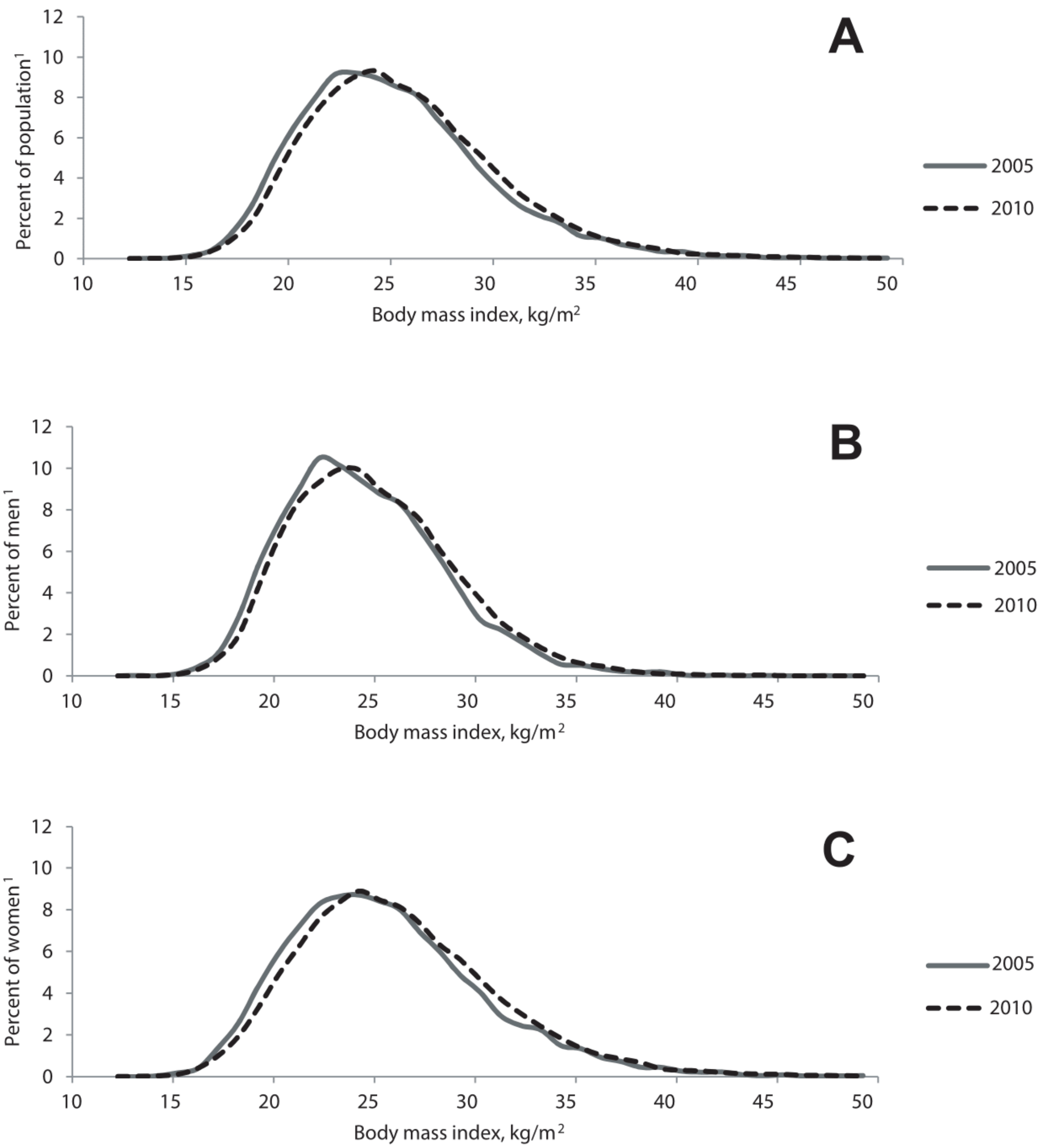
[3] P values are from the Rao-Scott Chi-Square test for sex, marital status, urban/rural, and region. For age, food security, and wealth index, P values represent a test for trend from unadjusted Poisson regression models with obesity as the outcome and a variable representing categories of the ordinal correlate as a continuous predictor.

Table 4.2: Adjusted prevalence ratios (PR) for obesity (BMI ≥30 kg/m^2) in Colombian adults in 2005 and 2010

	2005		2010	
	PR	95% CI[1]	PR	95% CI
Sex				
Male	0.56	(0.50, 0.61)	0.60	(0.57, 0.62)
Female	1.00		1.00	
Age, years				
18-24	0.44	(0.35, 0.54)	0.50	(0.46, 0.54)
25-34	1.00		1.00	
35-44	1.50	(1.33, 1.69)	1.36	(1.29, 1.44)
45-54	2.01	(1.78, 2.27)	1.67	(1.59, 1.77)
55-64	2.00	(1.77, 2.27)	1.85	(1.74, 1.96)
Marital status				
Married	0.99	(0.90, 1.09)	0.98	(0.93, 1.02)
Living Together	1.00		1.00	
Never Married	0.65	(0.56, 0.74)	0.66	(0.62, 0.71)
Separated	0.81	(0.72, 0.92)	0.78	(0.74, 0.83)
Widowed	1.02	(0.85, 1.23)	0.98	(0.90, 1.07)
Food security				
Food Secure	1.00		1.00	
Mild Food Insecurity	1.07	(0.97, 1.17)	0.99	(0.95, 1.03)
Moderate Food Insecurity	1.00	(0.86, 1.15)	0.98	(0.91, 1.04)
Severe Food Insecurity	1.18	(0.90, 1.55)	0.89	(0.79, 1.00)
Wealth index quintile				
1- Poorest	1.00		1.00	
2	1.71	(1.39, 2.10)	1.33	(1.24, 1.43)
3	1.84	(1.45, 2.35)	1.31	(1.21, 1.42)
4	2.06	(1.62, 2.62)	1.38	(1.27, 1.50)
5- Wealthiest	2.12	(1.66, 2.71)	1.32	(1.20, 1.44)
Urbanicity				
Urban area	1.00		1.00	
Small rural village	1.11	(0.96, 1.29)	0.92	(0.85, 1.00)
Disperse rural area	1.09	(0.84, 1.41)	0.86	(0.79, 0.93)
Region				
Atlantic	1.01	(0.90, 1.14)	1.06	(1.00, 1.12)
Oriental	1.07	(0.94, 1.21)	1.05	(0.99, 1.11)
Central	1.00		1.00	
Pacific	1.16	(1.02, 1.32)	1.08	(1.02, 1.15)
Bogotá	0.92	(0.78, 1.09)	0.80	(0.74, 0.86)
National Territories	1.42	(1.26, 1.60)	1.18	(1.10, 1.27)

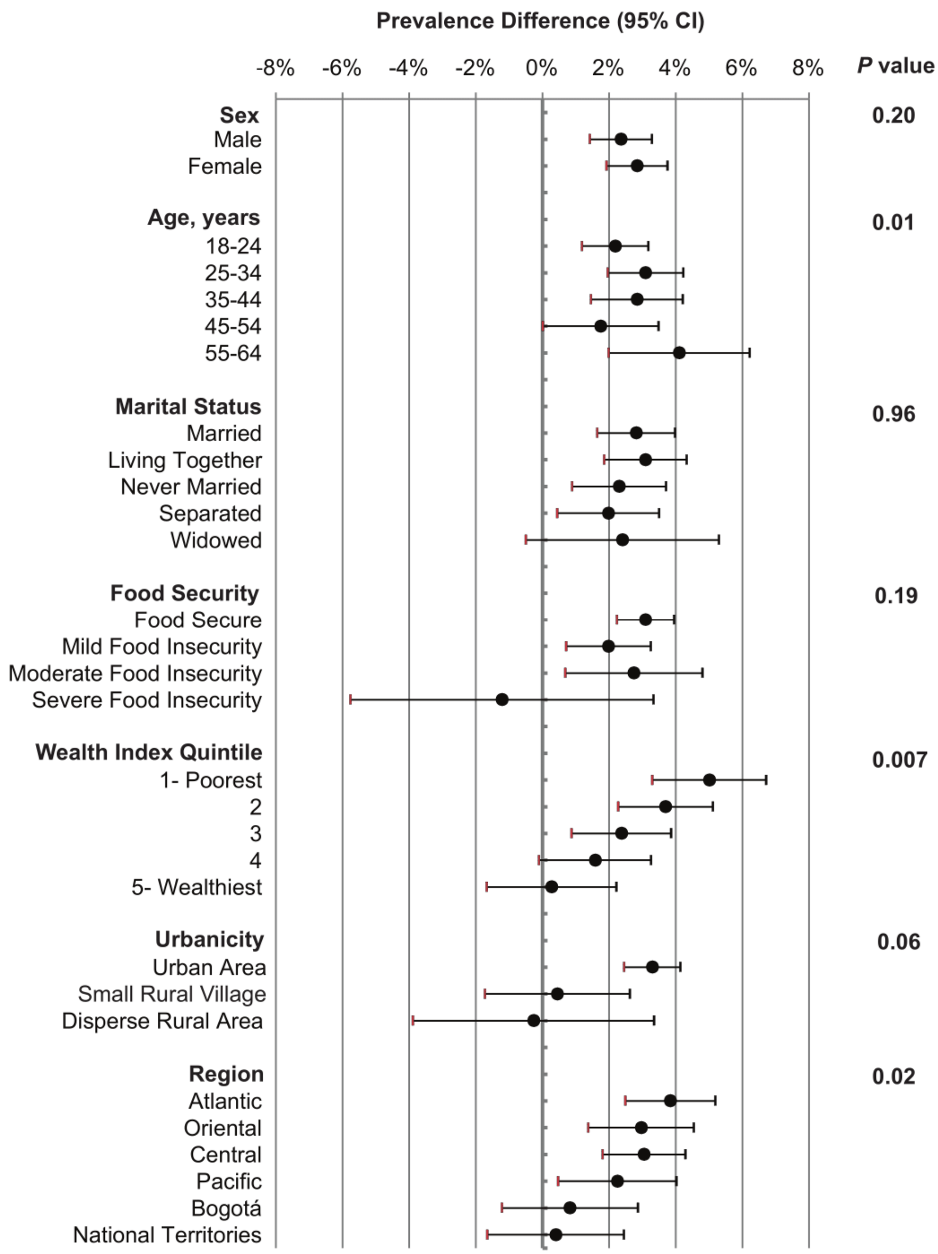
[1] Prevalence ratios and 95% confidence intervals are from Poisson regression with obesity as the dichotomous outcome and predictors that included indicator variables for male sex (female as reference), age (four indicators with “25-34” as reference), marital status (four indicators with “living together” as reference), food security (three indicators with “food secure” as reference), wealth index quintile (four indicators with “1-poorest” as reference), urbanicity (two indicators with “urban area” as reference), and region of residence (five indicators with “Central” as reference). The complex sampling survey design was taken into account in the multivariable regression. One model was fitted for each year.

Figure 4.1: BMI distribution in Colombian adults in 2005 and 2010. A: Total population; B: Men; C: Women.



[1] Represents the percent of population for a one unit change in BMI.

Figure 4.2: Adjusted obesity prevalence differences between 2005 and 2010 among Colombian adults.



Prevalence differences and 95% confidence intervals are from Poisson regression models with obesity as the dichotomous outcome and predictors that included indicator variables for each sociodemographic correlate, year 2010 (2005 as reference), and cross-product (interaction) terms between year and the indicator variables of the correlate. In addition, each model was adjusted for all other sociodemographic correlates including indicator variables for male sex (female as reference), age (four indicators with "25-34" as reference), marital status (four indicators with "living together" as reference), food security (three indicators with "food secure" as reference), wealth index quintile (four indicators with "1-poorest" as reference), urbanicity (two indicators with "urban area" as reference), and region of residence (five indicators with "Central" as reference). The complex sampling survey design was taken into account in all multivariable regression models. P values are from adjusted Wald tests for interaction between year and categories of each sociodemographic characteristic.

CHAPTER 5

Discussion

In this dissertation, we examined the relationship between the individual and the food environment in three distinct populations, at three different levels of the food environment. First, we assessed the relationship between the sociodemographic characteristics of a parent and child and the healthfulness of meals served during a home dinner in a population of low-income Midwestern children. We also described a novel tool for measuring the healthfulness of meals served to children in the home. Next, we assessed the relationship between individual level and food environment level characteristics with choice of grocery store in a population of college students in a large Midwestern public University. Finally, we assessed the differential effect of changes in the food environment during the Nutrition Transition on obesity prevalence by individual and environmental characteristics in a nationally representative sample of Colombian adults. We found evidence for a dynamic relationship between the food environment and the individual within each of these studies. In the first two studies, we found that the food environment to which an individual is exposed is dependent on characteristics of the individual, that is the healthfulness of meals served and the choice of grocery store were associated with sociodemographic characteristics. In the second study, we found that food environment characteristics additionally influenced grocery store choice, providing evidence for a dynamic association between the individual and the food environment. In the third study, we found that changes in the food environment affected individuals differently by socioeconomic status. In addition, we found that obesity prevalence was associated with environment variables, geographic region and urbanicity, again providing evidence for a dynamic relationship between the individual and food environment.

Following, we will examine the relationships found in each of the three studies for specific individual and environmental characteristics and relate our findings to the conceptual models described in the Introduction of this dissertation. We use the conceptual model proposed by Lytle, which describes that the degree to which individual choice and the environment depends on the level of restriction that an individual faces (Lytle, 2009). We define restriction to be to absence of access and utilize the five A's of access (availability, accessibility, accommodation, affordability, and acceptability) to understand the level of restriction that an individual may face, given his/her sociodemographic characteristics (Penchansky & Thomas, 1981).

Sex

We found differences in the relationship between the food environment and individual by sex within two of the three studies. In Chapter 2, we observed that parents served healthier meals to girls. In Chapter 3, we observed that male students shopped at less expensive grocery stores than females. However, in Chapter 4, while we did find a greater prevalence of obesity in females, we did not see a difference in the incidence of obesity associated with changes in the food environment.

We hypothesize that differences observed by gender are driven by both restrictive factors and by personal choice. Previous research has found that girls have higher diet quality than boys (Lorson, Melgar-Quinonez, & Taylor, 2009; Rasmussen et al., 2006; Torres, Santos, Orraca, Elias, & Palacios, 2014; Xie, Gilliland, Li, & Rockett, 2003), and that they have a greater preference for healthier foods (Granner et al., 2004; Robinson & Thomas, 2004). Research in adults has found that women place higher priority on eating specific diets, 'healthy' foods, and ethical considerations (Beardsworth et al., 2002; Bellows, Alcaraz V., & Hallman, 2010), which could lead to a greater preference for stores which prioritize organic and specialty food choices, and that males place higher importance on objective measures of value, such as price (Mortimer & Clarke, 2011). On the other hand, females in some populations may face greater restriction than males; however, this was not observed within our sample, which was restricted to college students.

Within the Colombian population, it is possible that restriction played a role in the higher obesity rates observed in women compared to men. In other countries, women have been affected by the Nutrition Transition before men (Monteiro, Moura, Conde, & Popkin, 2004). In our study, while obesity prevalence increased most in both men and women in the lowest wealth quintiles, the trend in increase by wealth was more pronounced in women than men. This observation may indicate a dynamic relationship between gender and the food environment.

Within families, parents act as gatekeepers of the food available to children, thus introducing the potential for restriction within this population. In fact, child gender has also been previously shown to be associated with parental feeding behavior (Fisher & Birch, 1999). In one experimental study overweight mothers served meals to boys that contained a higher content of food characterized as 'unhealthy' than in meals served to girls (Bouhlal, McBride, Ward, & Persky, 2015). In our study, we found that parents served healthier meals to females. As the foods available to female children were more restricted than male children, in terms of choice, this indicates that female children are able to exhibit a lesser degree of choice in their diet. Yet, this choice restriction may lead to a healthier diet. An important consideration of this model is that reduction in restriction does not necessarily lead to an improved diet that is determined by the individual's preferences when restriction is low, in comparison to the environmental influence when restriction is high.

Age

We assessed the relationship between age and the food environment in all three studies, with mixed findings. In Chapter 2, we did not find any association of child age with HMI scores- however the age group was restricted to children between 4 and 8 years. In Chapter 3, we found that younger students shopped at less expensive stores. In Chapter 4, while we did find statistically significant evidence for an interaction between age and changes in the food environment, there was not an observable or consistent trend between age groups.

Previous studies of US children have shown that consumption of milk, fruits, and vegetables decrease with age (Kamphuis et al., 2006; L. A. Lytle, Seifert, Greenstein, & McGovern, 2000). However, it is possible that overall dietary changes that occur throughout childhood are driven by changes in the school food environment and exposure to more foods outside the home as children age, which would be indicative of restriction faced by children in their dietary choices and constraints imposed by food environment influences.

In college, younger students may face greater restriction, with fewer resources, financial, educational, or otherwise, leading them to shop at less expensive stores. For example, younger students have may have less income, be less likely to own a car, have fewer resources for cooking, and may have less knowledge about food preparation, transportation n options, and food outlets. These restrictive factors may limit the feasible options for some students.

Race/Ethnicity

We assessed the relationship between race/ethnicity and the food environment in the first two of the three studies and found evidence for a relationship in only one of these. In Chapter 2, we found no association between parental race/ethnicity and meal healthfulness. In Chapter 3, we found that Asian and underrepresented minority students shopped at less expensive grocery stores than white students.

The relationship between race/ethnicity and grocery store choice may indicate a prioritization of low prices over other factors for these student groups, potentially due to greater economic restriction for some students, but may also be reflective of personal preference for certain store characteristics. Studies in the business literature have found associations of grocery store choice with race/ethnicity; African Americans were more likely to shop at supercenters than Caucasians (Carpenter & Moore, 2006). In addition, cultural preferences for store type have been previously proposed to be a determinant of store choice (Cummins, 2007). Culture is likely to be associated with race and ethnicity and may underlie some of our findings, though we were not able to measure the nuances of culture within our study.

While we did not find any associations of race/ethnicity with HMI scores, previous literature on associations between race and diet quality in children has been mixed (Crawford et al., 1995; de Hoog et al., 2014; Erinosho et al., 2012; Kamphuis et al., 2006; Xie et al., 2003).

Socioeconomic status- other dimensions

We assessed additional dimensions of socioeconomic status in each chapter, each in different ways. In Chapter 2, we assessed the relationship between parental education and HMI scores. In Chapter 3, we analyzed food security, transportation and fruit and vegetable intake, each which may represent certain aspects of economic or social constraints. In Chapter 4, we assessed wealth and food insecurity. Each of the dimensions of SES described in this section can be conceptualized as direct or indirect measures of restriction

Education: In Chapter 2, we found that greater parental education was associated with higher HMI scores. Prior literature has consistently found parental education to be associated with higher diet quality of children (Crawford et al., 1995; Rasmussen et al., 2006; Xie et al., 2003). Education is likely to be associated with financial resources and may also be associated with knowledge about how to prepare healthful meals.

Fruit and Vegetable Intake: We found that students who ate more FV servings were more likely to shop at more expensive stores. This relationship is likely driven by both individual choice and restriction, depending on the end of the restriction spectrum where an individual falls. For example, for students with high economic restriction, they are likely to be constrained to shopping at less expensive stores. Within the stores where they shop, these students may be further restricted to purchasing foods that are cheaper per calorie, and forgoing more expensive foods, such as fruits and vegetables. For students with low levels of restriction, those who prioritize healthy eating may have a preference for the more expensive stores.

In addition, fruit and vegetable intake may be associated with aspects of the food environment and of interactions between the individual and the food environment. FV intake may be associated with the affordability, availability, accessibility, and acceptability aspects of access. Affordability, as fruits and vegetables are more expensive per calorie than other foods; availability because fruits and vegetables may not be available at all food outlets; accessibility because the distance to the food outlets selling fresh produce may limit access; and acceptability because the fruits and vegetables available may not be culturally appropriate. Some of our previous unpublished research and conversations with students supports these ideas. Students have reported that it is difficult for them to purchase fruits and vegetables because they are expensive and perishable. They've reported not being able to go to the grocery store frequently enough to purchase fresh produce. International students have reported that the produce available is not familiar to them; they don't know what to buy or how to prepare it. The intersections between individual and food environment level restriction indicate existence of a dynamic relationship between the two.

Food Insecurity: We assessed the relationships between food insecurity and the food environment in Chapters 3 and 4. In Chapter 3, although the relationship was not statistically significant, the coefficients for food insecure students indicated that they shopped at less expensive stores. In Chapter 4, we found that food insecurity was associated with lower risk of obesity in 2005 and 2010, but that there was no difference in obesity incidence by food security status. Food insecurity is a measure of perceived restriction of diet due to affordability. In countries in later stages of the Nutrition Transition, severe food insecurity has been related to increased prevalence of obesity (Kac et al., 2012; Leung, Williams, & Villamor, 2012) whereas in countries at earlier stages, it is related to underweight (Isanaka, Mora-Plazas, Lopez-Arana, Baylin, & Villamor, 2007). While, we did not find evidence for an interaction between food insecurity and the food environment in these studies, it is possible that the relationships were captured within the other, more objective, variables we studied that were collinear with food insecurity, such as wealth and SES.

Transportation: We assessed the relationship between transportation and grocery store choice in Chapter 3, finding that students who utilized a car to get to the grocery store shopped at stores with lower prices. This relationship may represent aspects of both individual choice and restriction. Previous research has shown travel mode to the store to be influenced independently by the distance to store and by car ownership (Jiao, Moudon, & Drewnowski, 2011). In the future, we could devise models to determine the independent effects of car ownership and distance to store on use of car transportation in order to parse out the degree to which each influences our results. Our findings may represent prioritization of alternative transportation for some students, who therefore travel shorter distances and frequent more expensive stores that are closer. It may also be due to constraints faced by students who do not have access to a car and cannot travel as far and thus have a lesser degree of choice in which grocery store at which they shop, and must therefore shop at the closer, more expensive, stores. The results of our study may not be generalizable to other populations with different characteristics, as our study was restricted to college students. Car ownership in our study was much lower than would be found in other US populations; however this may have improved our ability to determine associations by car transport.

Wealth: In Chapter 4, we found that while wealth was related to obesity in each survey year, there was a strong gradient in prevalence change between survey years by wealth index. The prevalence of obesity increased by 5% over the five –year study period in the poorest people but there was virtually no change during that time period in the wealthiest. The shift in the burden of obesity from the richer to the poorer has been documented as countries move through economic development. In a review of studies from 14 countries, Monteiro et. al found that the reversal of the association between obesity and SES occurs when countries have greater per capita gross national product (GNP) (Monteiro et al., 2004). While wealth is most directly associated with the affordability aspect of access, there are additional aspects of access that maybe associated with wealth. For example, wealth may dictate the resources available in the neighborhood where are person lives; it may determine the availability and reliability of transportation; and it may influence the acceptability of certain foods or stores for an individual. An alternate explanation for the trends in obesity by wealth index could be that as incomes rise within the country, restriction within the lowest wealth quintiles decreases, leading to greater personal preference in food choices and increased obesity as a result.

Environmental Characteristics

In Chapters 3 and 4, we analyzed the relationship between different aspects of the environment and their influence on the food environment exposure. In Chapter 2, the home food environment was measured as an outcome, though we did not measure the influence of the built food environment. As socioeconomic disparities in food access are prevalent in the United States, it is possible that the local food environment played a role in the relationships we found(Ball, Timperio, & Crawford, 2009). Furthermore, although we included parental characteristics above as individual-level factors, for consistency with the other studies, parental characteristics may also be viewed as components of the food environment to which a child is exposed, Within the ecological model, they would be a part of the social environment, lying between the individual (child) and the physical food environment. Furthermore, as descried above, many of the individual characteristics in each of the studies may reflect the intersection between the individual and the food environment. In the dynamic model I propose in this dissertation, the two cannot be fully disentangled and act simultaneously to influence individual-level restriction.

Distance to Grocery Stores: In Chapter 3, we found that distance to any grocery store does not influence choice of grocery store. However, when price of grocery store was taken into account, distance to the lower priced tertiles did influence store choice, though distance to the highest priced tertile did not impact store choice. This may reflect that accessibility alone is not sufficient, but that affordability also plays a role in grocery store choice. Another study characterized the availability of food outlets that are too expensive for specific populations as 'food mirages'(Breyer & Voss-Andreae, 2013). This description may inform our research and provide an explanation for the reason that students travel much further to reach lower priced stores, even if higher priced stores are more accessible geographically. In the Penchansky and Thomas model of access, accessibility does not matter if the affordability criterion is not met (Penchansky & Thomas, 1981).

Urbanicity and Region: In Chapter 4, we found that obesity prevalence was highest in urban areas in 2005 and 2010 and that prevalence was growing faster in urban than rural areas. We also found a geographical gradient of the recent changes in obesity prevalence, with the highest increase observed in the Atlantic region, followed by the Oriental, Central, and Pacific regions, and virtually no change in Bogota or the National Territories. Changes in the food system may not have been evenly distributed geographically. Decreased physical activity and increased consumption of high energy foods related to urbanization have been identified as major contributors to the rise in obesity prevalence worldwide (Malik, Willett, & Hu, 2013). It is possible that region-specific changes in food availability or physical activity patterns occurred during this period. Between 2005 and 2010, imports of food products in Colombia doubled (Food and Agriculture Orgnization of the United Nations, 2013) potentially enhancing exposure to a more 'Western' diet, which has been associated with risk of obesity(Hawkes, Chopra, & Friel, 2003).

Conclusions

Future studies of the food environment should consider carefully the role of the individual interacting with the environment, both as a predictor of exposure to the food environment and as a modifier of the effects of the food environment. Additionally, a broader perspective on the concept of access should be considered. As the framework for the 5 A's of Access describes, the system is only as strong as the weakest dimension of access. Therefore, studies that address only one aspect of access, such as distance to store, may not accurately capture food access, as it relates to individuals within a population. In particular, affordability should be more systematically integrated into studies of the food environment. Finally, the role of individual choice within the food environment should be examined as individual choice does not necessarily equate to healthy choice. While an increase in access will improve individual autonomy, assumptions that it will be correlated to improved dietary outcomes may be unmerited.

Policy makers and public health practitioners that seek to improve health through changing the food environment should take time to carefully consider how the individuals, with different sociodemographic characteristics, within the target population interact with the food environment and the implications of this interaction for the effects of a program or policy. Each dimension of access should be assessed in order to determine the best course of action for a given community, taken into consideration the concept that the weakest link is indicative of the strength of the system. Multi-level programs and policies that address the individual in addition to the food environment should be considered

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Appendix A

Healthy Meal Index Coding Materials

Coding Instructions

Overall directions

1. If there is a question about a food item, do not code this meal, set aside and ask for Master Coder's opinion
2. Do not include condiments (gravy, croutons, parmesan cheese, ketchup, mustard, sour cream, relish, salad dressing, etc.)
3. Include all food that was available even if it is stated that the index child did not consume that food
4. Some foods will be coded in multiple questions
    a. For example: pancakes will be coded as a grain and coded separately as a dessert

Mixed Dish

1. Refer to "Mixed Dish List" for a list of mixed dishes that should be recorded as a mixed dish
2. Record "Yes" if a mixed dish is present, record "No" if there is no mixed dish.
    a. If you believe an item is a mixed dish but not on the mixed dish list, do not code this meal, set aside and ask for Master Coder's opinion
3. Write in what the dish is.
    a. Ex: If lasagna is serve, record "Yes" and write in "lasagna"
4. For coding the mixed dish, refer to the "Mixed Dish List." Compare description of meal described in meal report to the food groups listed in the "Mixed Dish List." If the details differ, then code according to the meal report; if the details do not differ or if details are not specified in the meal report, code exactly as stated in "Mixed Dish List."

a. Ex: If it is stated that pizza was served with whole-wheat dough, record the grain as "whole," and everything else exactly as stated in the "Mixed Dish List."
b. Ex: If it is stated that chili dogs were served, record for both hot dogs and chili (note: both chili and hot dogs contain beef/pork, only record beef/pork once)
c. Ex: If it is stated that beef raviolis were served, record exactly as it states on "Mixed Dish List" for raviolis, and in addition record "beef/pork."
d. Ex: If a ham sandwich was served, refer to "Mixed Dish List" and record for a "Sandwich/Sub," but instead of "1 poultry" record protein as "1 beef/pork."

<u>Fruit</u>

1. Record whether fruit is present or absent at the meal
2. If fruit is present, write in how many types of fruit there are
    a. Ex. If apple and strawberry are present, write 2
3. Do not include fruit flavored items (i.e. strawberry pudding)
4. Do not record fruit juice (even 100%) as a fruit

<u>Vegetable</u>

1. Record whether vegetable(s) is present or absent at the meal
2. If vegetable is present, write in how many types of vegetables there are
    a. Note: not all vegetables may be present in any of the vegetable categories, still include in overall vegetables
3. If vegetable is present, record if potato(s) is present or absent
    a. If present, record if potato is fried, not fried, or not specified (NS)
4. If vegetable is present, record if dark green, red or orange, avocado, and/or legume is/are present

Grain

1. Record whether a grain is present or absent.
2. If specified, record if grain(s) is whole, refined or not specified.
    a. Refer to list of grains for what classifies as a grain, and what classifies as either whole or refined for that grain.
    b. If multiple grains are present, record all types of grain (whole, refined, NS) that are present
3. If a protein is breaded (ie fried chicken), DO NOT record it as a grain, only record it as a protein.

Protein

1. Record whether a protein source is present or absent
2. If present, record whether protein is deep-fried, or not fried (includes any other cooking method)/NS. If multiple cooking methods are used, record all that apply
3. Record all protein sources that are present

Dairy

1. Record if dairy (includes soy alternatives) is present or absent
2. If milk is present, record "milk"
    a. If milk is specified as: skim/low-fat(1%), 2%, whole, flavored, soy, or NS, record as such
3. If other dairy sources are available, record all that are present. If you believe a dairy item is served but is not on the list, pull-for-an-ask
4. Cheese – includes cheese sauces (i.e. "vegetables with cheese sauce")

Non-Dairy Sweets/Desserts

1. Record whether a sweet/dessert is present or absent.

Non-Dairy Beverages

1. If the juice is orange juice or apple juice, or Juice Box (any fruit but cranberry) or Juicy Juice (any fruit, including cranberry), mark as "100% juice"
2. If the juice is cranberry juice (excluding Juicy Juice brand), mark as a SSB (unless specified that the cranberry juice is 100% cranberry juice)
3. If a drink does not fall into any other category, do not code this meal, set aside and ask for Master Coder's opinion
4. Note: a beverage **cannot** be both a SSB and 100% juice; hot chocolate does NOT get recorded for "milk" unless specifically stated that hot chocolate is made with milk

Fast food/pre-packaged/highly processed:

1. Refer to the "Highly Processed" column of the "Mixed Dish List" for foods that should be recorded, unless specifically stated as homemade
2. Items that are not on Mixed Dish List but that should be considered as Fast food/pre-packaged/highly processed:
    a. Any frozen dinner: Lean Cuisine,

Not Otherwise Specified high fat food

1. Refer to list on coding template for foods that should be recorded as "not otherwise specified high fat food"

FMO Number: ______ ID Number: __________ Coder:___________________

1. Mixed dish Available? (Please see "Mixed Dish List" for a list of mixed dishes)

□ **Yes** □ **No**

If yes, specify **Type of Mixed Dish(es)**: **______________________**

(Please see 'Mixed Dish List' for how to code each mixed dish)

2. Fruit Available?

□**Yes - #__________** □ **No**

3. Vegetable and/or Legume Available?

□ **Yes - #__________** □ **No**

If yes, specify if any of these **Types of Vegetables** were present **(choose all that apply)**

Note: Not all vegetables will fall into any of the following categories, still include in overall vegetables.

□Potato (do **NOT** include potato chips)

□Fried □Mashed □Not fried or mashed □NS

Fried potatoes = French fries, tater totes, hash browns

□Dark green vegetable, includes only:

Bok Choy	*Kale*	*Spinach*
Broccoli	*Mesclum*	*Turnip greens*
Collard greens	*Mustard greens*	*Watercress*
Dark green leafy lettuce	*Romaine lettuce*	

□Red or orange vegetable, includes only:

Acorn squash	*Hubbard squash*	*Sweet potatoes*
Butternut squash	*Red peppers*	*Tomatoes*
Carrots	*Pumpkin*	*Tomato juice*

□Avocado

□Legumes (beans, peas and lentils, do NOT include green beans)

4. Grain Available?

□Yes □No

If yes, specify **Type of Grain** (Choose all that apply)

□Whole □Refined □ NS

Whole Grain includes

whole wheat, whole grain, or multigrain bread, bagels, English muffins, biscuits, pancakes, crackers, tortillas or pasta

oatmeal	*quinoa*	*bulgur*
brown or wild rice	*buckwheat*	*popcorn*

Refined Grain includes

white or enriched bread, bagels, English muffins, biscuits, pancakes, crackers, tortillas or pasta

plain, egg bagel	*cornbread*	*puffed rice*
buttermilk/plain pancakes	*saltine crackers*	
biscuits	*corn flakes*	

5. Protein Available (does **NOT** include legumes)

□ **Yes** □ **No**

If yes, specify **Preparation of the Protein** (Choose all that apply)

□Deep fried *(Includes chicken tenders/strips/nuggets/fries)* □Not fried or NS

If yes, specify **Type of Protein** (Choose all that apply)

□Poultry	□Fish/Shellfish	□ Nuts and seeds
□ Beef/Pork	□Meat substitute	□NS
□Egg		

6. Dairy Available (includes soy alternatives)?

□ **Yes** □ **No**

If yes, specify **Type of Dairy** (Choose all that apply)

□Milk

->Type of milk (Choose all that apply)

□Skim/low-fat(1%) □2% □whole □ Flavored □ Soy □ NS

□Cheese (**NOT** Cottage Cheese)	□Cream sauce/soup	□ Frozen Yogurt
□Cottage Cheese	□Yogurt (**NOT** frozen yogurt)	□Pudding
		□ Ice Cream

7. Non-Dairy Sweets/Desserts Available? *Includes Cake, Candy, Cookies, Brownies, Doughnuts, French Toast, Jello, Pancakes, French toast*

□ **Yes** □ **No**

8. Non-Dairy Beverages Available?

□ **Yes** □ **No**

If yes, specify **Type of Beverage** (Choose all that apply)

□Sugar Sweetened Beverage (SSB) *(includes all sodas, Kool-aid, Bug Juice, Juice Squeeze, Iced Tea, Capri Sun, Fuze, Lemonade, Sunny D, Yoplait smoothie, hot chocolate)*

□ Diet beverages □100% Juice □ Water □ Coffee/Hot Tea

9. Other

□**Main Dish: Fast food/Pre-packaged/Highly processed**

Main dish from any restaurant *Chicken tenders/strips/nuggets/fries*

Fish sticks

**Refer to "Mixed Dish List" for foods qualifying as fast food/pre-packaged/highly processed*

□**Not Otherwise Specified high fat food present,** includes:

Pot pie (any kind)	*Tortilla chips*	*Biscuits*
Egg rolls	*Cheetos*	*Scones*
Garlic bread	*Doritos*	Nachos
Potato chips	*Coleslaw*	
	Macaroni/potato salad	

Table SA.1: Mixed Dish List

Mixed Dish	Fruit	Vegetable	Grain	Protein	Dairy	Highly processed
Breakfast sandwich	0	0	1 (refined)	1 (beef/pork)	1 (cheese)	X
Burrito	0	2 (1 red/orange, 1 legume)	1 (refined)	0	1 (cheese)	
Canned pasta (ie Spaghetti O's)	0	1 (red/orange)	1 (refined)	0	0	X
Cheeseburger	0	1	1 (refined)	1 (beef/pork)	1 (cheese)	
Chicken carbonara	0	1	1 (refined)	2 (1 poultry, 1 beef/pork)	1 (cheese)	
Chicken vegetable soup/ Chicken noodle soup	0	2	1 (refined)	1 (poultry)	0	
Chili	0	2 (1 red/orange, 1 legume)	0	1 (beef/pork)	0	
Cream of tomato soup	0	1 (red/orange)	0	0	1 (milk, whole)	X
Egg roll	0	1	1 (refined)	1 (beef/pork)	0	X
Fried rice	0	2	1 (refined)	1 (poultry)	0	X
Hamburger helper	0	1	1 (refined)	1 (beef/pork)	0	X
Hot dogs/ corn dogs	0	0	1 (refined)	1 (beef/pork)	0	X
Lasagna	0	2 (1 red/orange)	1 (refined)	1 (beef/pork)	1 (cheese)	X
Lentil soup	0	2 (1 red/orange,	0	0	0	

		1 legume)				
Lo mein	0	2	1 (refined)	1 (beef/pork)	0	**X**
Macaroni and cheese	0	0	1 (refined)	0	1 (cheese)	**X**
Mixed vegetables	0	3 (1 red/orange)	0	0	0	
Pasta salad	0	2	1 (refined)	0	0	
Peanut butter & jelly sandwich	0	0	1 (refined)	1 (nuts and seeds)	0	
Pizza with cheese	0	1 (red/orange)	1 (refined)	0	1 (cheese)	**X**
Pot pie	0	3(1 red/orange, 1 legume)	1 (refined)	1 (poultry)	0	**X**
Quesadilla	0	0	1 (refined)	0	1 (cheese)	
Raviolis, tortellinis	0	1	1 (refined)	0	1 (cheese)	**X**
Salad	0	2	0	0	0	
Sandwich/Sub	0	2 (1 red/orange)	1 (refined)	1 (poultry)	1 (cheese)	
Sloppy Joes	0	1	1 (refined)	1 (beef/pork)	0	
Spaghetti, Goulash	0	1 (red/orange)	1 (refined)	1 (beef/pork)	0	
Stir-fry	0	2 (1 red/orange)	0	1 (beef/pork)	0	
Stuffed peppers	0	2	1 (refined)	1 1/2	0	
Sushi	0	2	1 (refined)	1 (fish/shellfish)	0	
Tacos, Enchiladas, Fajitas	0	2 (1 red/orange)	1 (refined)	1 (beef/pork)	1 (cheese)	
Tuna noodle	0	0	1 (refined)	1	1 (cheese)	**X**

casserole				(fish/shellfish)		
Tuna salad sandwich	0	2	1 (refined)	1 (fish/shellfish)	0	
Fruit Cocktail	2	0	0	0	0	
Chicken parmesan	0	1 (red/orange)	0	1 (poultry, fried)	1 (cheese)	
Chicken Alfredo	0	0	1 (refined)	1 (poultry)	1 (cream sauce)	
Shepard's Pie	0	2 (1 potato, mashed, 1 red/orange)	0	1 (beef/pork)	0	

Appendix B

Market Basket Survey for Grocery Store Audit

Store Name Address Reviewer Names

Date

FRESH PRODUCE

Type	**Size**	**Lowest Price**	Quality (1-4)	Sale? (Y/N)	**Organic Price**	Qual ity (1-4)	Sale? (Y/N)	**Local Avail?**	***Comments*** *(include any differences in product type or size from the specified value)*
Apples	pound								
Bananas	pound								
Oranges	pound								
Grapes	pound								
Cantaloupe	1								
Carrots	pound								
Green Pepper	pound								
Red Pepper	pound								
Tomatoes	pound								
Broccoli	pound								
Onions	pound								
Potatoes	pound								
Romaine	1 head								
Celery	1 heart								
Mushrooms	8 oz								

DAIRY

Type	Size	Lowest Price	Sale? (Y/N)	Organic Price	Sale? (Y/N)	Local Avail?	***Comments*** *(include any differences in product type or size from the specified value)*
Skim or 1%	1						
Soy Milk	Half						
Cheddar Cheese	8 oz						
Cottage Cheese	16 oz						
Mozzarella	8 oz						
Plain Yogurt	32 oz						
Eggs	Dozen						
Tofu Blocks	14-16						

NONNPERISHABLE GOODS

Type	Size	Lowest Price	Size	Sale? (Y/N)	Organic Price	Size	Sale? (Y/N)	Local Avail?	*Comments*
Mandarin Oranges, in juice	14-16 oz								
Peaches, in juice	14-16 oz								
Spaghetti Sauce (jar)	24-26 oz								
Tomato Sauce (can)	15 oz								
Tunafish (can)	5 oz								
Black Beans (can)	15 oz								
Kidney Beans (can)	15 oz								
Peanut Butter (jar)	16 oz								
Whole Grain Noodles	32 oz								
Brown Rice	2 lb								
Plain Corn Flakes	10-14 oz								
Oatmeal	18 oz								
Olive Oil	25 oz								

FROZEN GOODS

Type	**Size**	**Lowest Price**	Size	Sale? (Y/N)	**Organic Price**	Size	Sale? (Y/N)	**Local Avail?**	***Comments***
Frozen Corn	10-12 oz								
Frozen Broccoli	16 oz								
Frozen Green Beans	10-12 oz								
Frozen Green Peas	10-12 oz								

MEAT

Type	**Size**	**Lowest Price**	Size	Sale? (Y/N)	**Organic Price**	Size	Sale? (Y/N)	**Local Avail?**	***Comments***
Lean Ground Beef (85%)	pound								
Chicken Breast	pound								
Ground Turkey	pound								
Salmon (fresh or frozen)	pound								
Tilapia (fresh or frozen)	pound								

BREADS

Type	**Size**	**Lowest Price**	Size	Sale? (Y/N)	**Organic Price**	Size	Sale? (Y/N)	**Local Avail?**	***Comments***
100% Whole Wheat Bread	1 loaf								
Plain Bagels	8 count								
Whole Grain Buns/Rolls	8 count								

Appendix C

Supplemental Tables from Chapter 4

Table SB.1. Percent of adult non-pregnant survey participants included in statistical analyses

	2005			2010		
	N[1]	Percent Included	SE[2]	N[1]	Percent Included	SE[2]
Sex						
Male	19,605	55.6	0.7	53,861	70.8	0.3
Female	20,684	85.1	0.5	58,279	87.1	0.2
Age, years						
18-24	8,911	70.2	0.9	23,454	78.9	0.4
25-34	10,543	69.0	0.8	28,478	77.5	0.4
35-44	9,282	71.2	0.7	25,171	80.0	0.4
45-54	7,218	71.2	0.8	21,277	80.5	0.4
55-64	4,335	73.1	1.0	13,760	81.0	0.5
Marital status						
Married	10,100	70.5	0.7	26,198	80.8	0.4
Living Together	13,407	72.6	0.7	40,425	81.2	0.3
Never Married	11,083	66.1	0.8	29,328	74.4	0.4
Separated	4,535	74.8	1.1	13,347	81.7	0.4
Widowed	1,149	81.7	1.6	2,813	85.9	0.8
Food security						
Food Secure	22,613	74.4	0.5	59,281	77.6	0.3
Mild Food Insecurity	9,897	74.8	0.7	33,528	81.3	0.3
Moderate Food Insecurity	4,350	78.1	0.9	15,249	82.1	0.4
Severe Food Insecurity	1,366	75.4	1.9	4,082	82.1	0.9
Wealth index quintile						
1- Poorest	7,169	71.5	1.2	29,537	82.9	0.4
2	10,079	75.0	0.8	26,048	82.9	0.4
3	9,070	70.7	0.9	21,791	81.5	0.4
4	7,680	71.1	0.9	18,123	77.5	0.5
5- Wealthiest	6,291	65.9	1.1	16,641	73.5	0.5
Urbanicity						
Urban area	32,218	70.0	0.6	80,156	78.3	0.3
Small rural village	4,430	76.0	1.2	18,890	83.4	0.5
Disperse rural area	3,641	69.0	1.4	13,094	82.4	0.5
Region						
Atlantic	9,214	76.3	0.8	24,666	80.8	0.4
Oriental	4,834	69.2	1.0	17,114	77.1	0.5
Central	8,058	70.9	0.9	28,108	82.2	0.4
Pacific	5,489	74.5	0.9	16,232	83.5	0.4
Bogotá	2,255	60.5	1.8	8,084	71.5	0.7
National Territories	10,439	69.1	1.2	17,936	85.9	0.5

[1] N refers to the total sample frequency for each category, excluding pregnant women (n= 1,707 in 2005 and n=1,793 in 2010). In 2005, 15 people and in 2010, 29 people had missing values for marital status. In 2005, 2,063 people had missing values for food insecurity.

[2] Percent included and standard error are weighted to represent the Colombian population and refer to the weighted percent of non-pregnant adults aged 18 to 64 included in the analyses.

Table SB.2. Prevalence of obesity in Colombian adult women in the National Nutrition Surveys of 2005 and 2010

	2005				2010			
	N[1]	% Obese	SE[2]	P[3]	N[1]	% Obese	SE[2]	P[3]
Age, years				<0.0001				<0.0001
18-24	3,977	4.1	0.4		10,284	6.7	0.3	
25-34	4,879	11.9	0.7		12,849	14.8	0.4	
35-44	4,415	19.6	0.8		11,929	21.9	0.5	
45-54	3,372	26.9	1.1		10,161	28.9	0.6	
55-64	2,036	29.2	1.3		6,403	32.6	0.7	
Marital status				<0.0001				<0.0001
Married	4,672	22.3	0.8		12,345	25.1	0.5	
Living Together	6,026	17.1	0.6		18,550	20.6	0.4	
Never Married	4,185	8.4	0.6		10,472	11.0	0.4	
Separated	2,887	17.2	1.0		8,092	20.8	0.5	
Widowed	902	27.3	2.2		2,160	30.4	1.2	
Food security				0.73				<0.0001
Food Secure	10,580	17.0	0.5		26,864	19.3	0.3	
Mild Food Insecurity	4,620	17.9	0.7		15,935	20.7	0.4	
Moderate Food Insecurity	1,999	16.0	1.1		6,972	21.7	0.7	
Severe Food Insecurity	624	18.9	2.2		1,856	20.4	1.3	
Wealth index quintile				0.001				0.12
1- Poorest	3,003	13.2	0.9		12,933	18.5	0.5	
2	4,698	17.1	0.8		12,222	22.0	0.5	
3	4,367	16.4	0.8		10,456	20.6	0.5	
4	3,711	18.7	0.8		8,543	20.5	0.5	
5- Wealthiest	2,900	17.9	1.0		7,473	18.5	0.5	
Urbanicity				0.16				0.98
City urban area	15,161	17.1	0.4		37,528	20.0	0.3	
Small village	2,029	17.7	1.0		8,465	20.2	0.7	
Disperse population	1,489	14.7	1.3		5,634	20.1	0.6	
Region				0.09				<0.0001
Atlantic	4,297	15.4	0.6		11,310	20.0	0.5	
Oriental	2,220	17.1	0.9		7,657	20.7	0.5	
Central	3,839	16.9	0.7		13,377	20.8	0.5	
Pacific	2,620	18.5	1.0		7,749	22.3	0.5	
Bogotá	951	16.8	1.4		3,482	16.1	0.7	
National Territories	4,752	20.5	1.0		8,052	21.2	0.7	

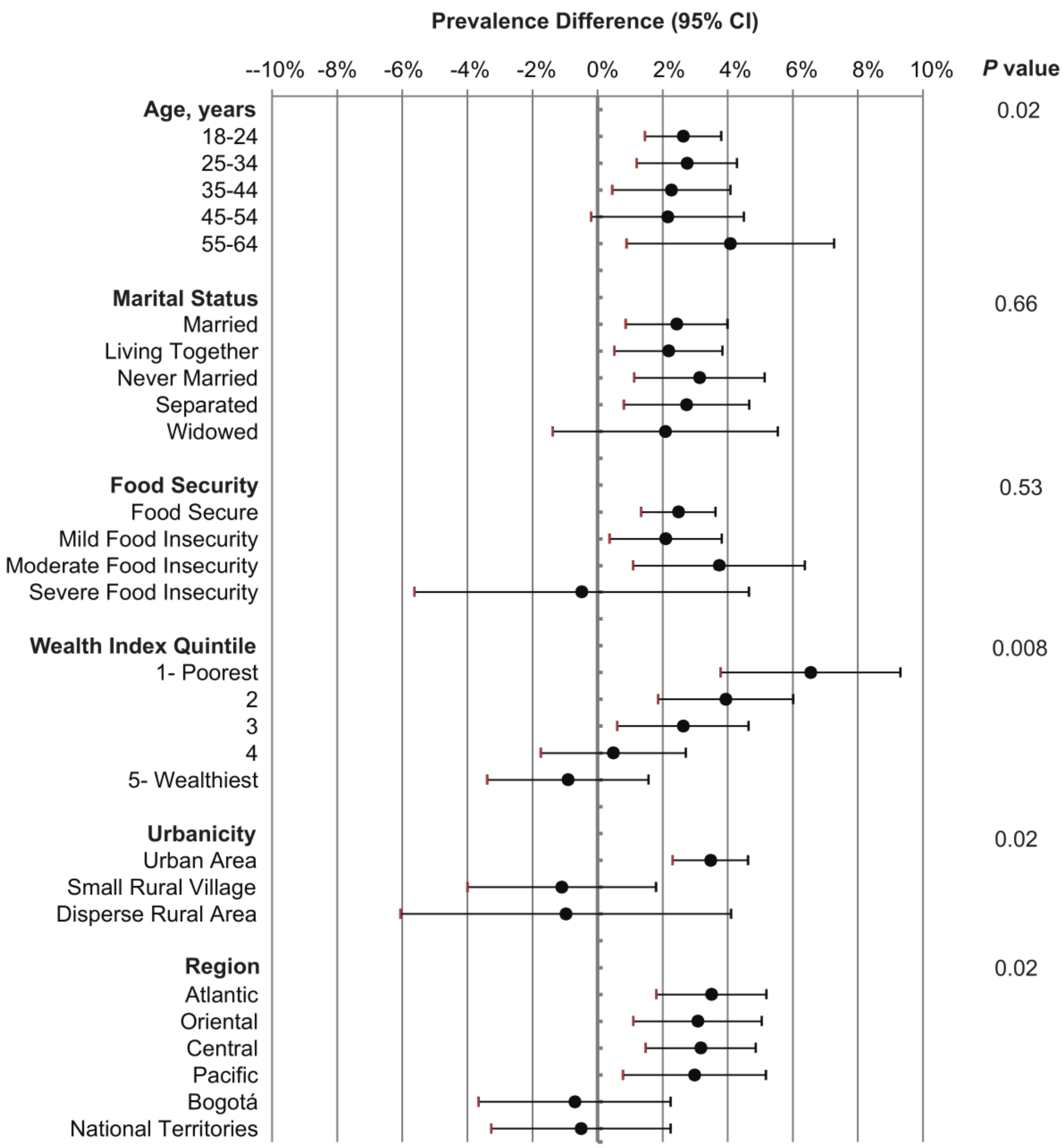
[1] N refers to the total sample frequency for each category. In 2005, 8 women and in 2010, 8 women had missing values for marital status and were excluded from the descriptive statistics of marital status. In 2005, 1,040 women had missing values for food insecurity and were excluded from the descriptive statistics of food insecurity.
[2] Percent obesity (BMI≥30 kg/m^{2}) and standard error are weighted to represent the Colombian population.
[3] P values are from the Rao-Scott Chi-Square test for marital status, urbanicity, and region. For age, food security, and wealth index quintile, P values represent a test for trend from unadjusted poisson regression models with obesity as the outcome and a variable representing categories of the ordinal correlate as a continuous predictor.

Table SB.3. Prevalence of obesity in Colombian adult men in the National Nutrition Surveys of 2005 and 2010

	2005				2010			
	N[1]	% Obese	SE[2]	p[3]	N[1]	% Obese	SE[2]	p[2]
Age, years				<0.0001				<0.0001
18-24	2,841	3.4	0.5		8,675	4.4	0.3	
25-34	3,174	7.8	0.7		9,917	11.1	0.4	
35-44	2,813	11.0	0.9		8,696	14.5	0.5	
45-54	2,217	14.2	1.2		7,270	14.6	0.5	
55-64	1,381	11.3	1.1		4,931	15.0	0.7	
Marital status				<0.0001				<0.0001
Married	3,116	13.7	0.9		9,216	16.8	0.5	
Living Together	4,486	9.4	0.6		15,075	13.5	0.4	
Never Married	3,872	4.5	0.5		11,886	5.8	0.3	
Separated	851	10.1	1.7		3,021	8.9	0.7	
Widowed	96	9.7	4.2		276	11.0	2.5	
Food security				0.005				<0.0001
Food Secure	6,936	10.3	0.6		20,514	13.6	0.3	
Mild Food Insecurity	3,017	8.1	0.7		11,782	9.9	0.3	
Moderate Food Insecurity	1,456	6.4	0.9		5,668	7.9	0.5	
Severe Food Insecurity	456	7.6	2.7		1,525	6.3	0.9	
Wealth index quintile				<0.0001				<0.0001
1- Poorest	2,460	2.8	0.4		11,832	5.5	0.3	
2	3,307	7.6	0.7		9,546	10.7	0.4	
3	2,694	9.8	0.8		7,449	11.7	0.4	
4	2,225	11.0	0.9		5,732	14.3	0.6	
5- Wealthiest	1,740	13.1	1.1		4,930	15.6	0.6	
Urbanicity				<0.0001				<0.0001
City urban area	9,766	10.3	0.5		26,787	12.9	0.3	
Small village	1,520	6.4	0.7		7,586	9.4	0.6	
Disperse population	1,140	3.6	0.6		5,116	6.4	0.4	
Region				0.01				0.03
Atlantic	3,008	8.6	0.7		8,954	12.3	0.4	
Oriental	1,296	9.9	1.0		5,563	12.2	0.5	
Central	2,293	8.1	0.8		9,624	10.8	0.4	
Pacific	1,766	10.4	1.0		5,929	11.0	0.5	
Bogotá	559	7.2	1.3		2,303	11.1	0.7	
National Territories	3,504	15.0	1.1		7,116	13.6	0.6	

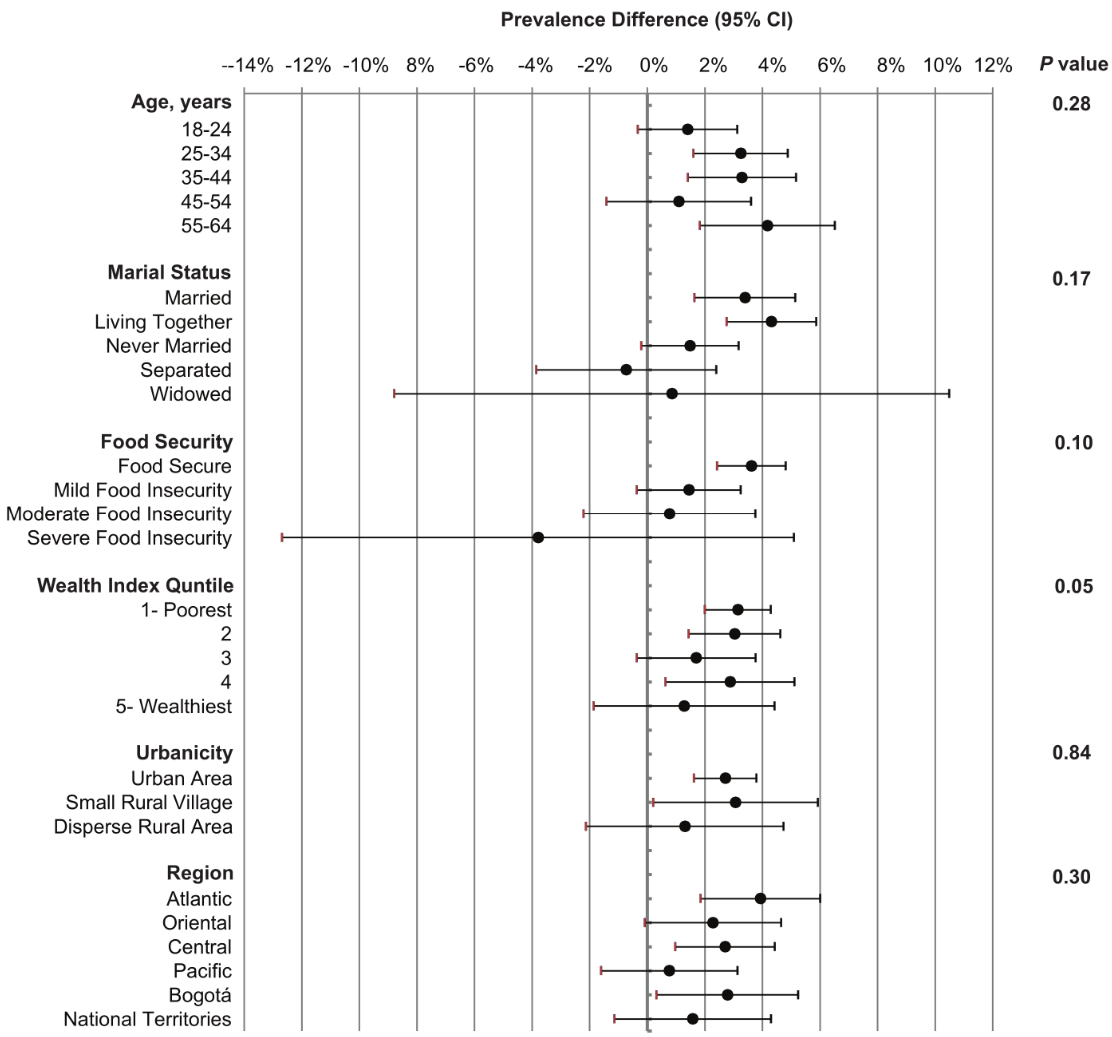
[1] N refers to the total sample frequency for each category. In 2005, 7 men and in 2010, 21 men had missing values for marital status and were excluded from the descriptive statistics of marital status. In 2005, 1,023 men had missing values for food insecurity and were excluded from the descriptive statistics of food insecurity.
[2] Percent obesity (BMI≥30 kg/m^{2}) and standard error are weighted to represent the Colombian population.
[3] P values are from the Rao-Scott Chi-Square test for marital status, urbanicity, and region. For age, food security, and wealth index quintile, P values represent a test for trend from unadjusted poisson regression models with obesity as the outcome and a variable representing categories of the ordinal correlate as a continuous predictor

Figure SB.1. Adjusted obesity prevalence differences between 2005 and 2010 among Colombian adult women



Prevalence differences and 95% confidence intervals are from poisson regression models with obesity as the dichotomous outcome and predictors that included indicator variables for each sociodemographic correlate, year 2010 (2005 as reference), and cross-product (interaction) terms between year and the indicator variables of the correlate. In addition, each model was adjusted for all other sociodemographic correlates including indicator variables for age (four indicators with “25-34” as reference), marital status (four indicators with “living together” as reference), food security (three indicators with “food secure” as reference), wealth index quintile (four indicators with “1-poorest” as reference), urbanicity (two indicators with “urban area” as reference), and region of residence (five indicators with “Central” as reference). The complex sampling survey design was taken into account in all multivariable regression models. P values are from adjusted Wald tests for interaction between year and categories of each sociodemographic characteristic.

Figure SB.2. Adjusted obesity prevalence differences between 2005 and 2010 among Colombian adult men



Prevalence differences and 95% confidence intervals are from poisson regression models with obesity as the dichotomous outcome and predictors that included indicator variables for each sociodemographic correlate, year 2010 (2005 as reference), and cross-product (interaction) terms between year and the indicator variables of the correlate. In addition, each model was adjusted for all other sociodemographic correlates including indicator variables for age (four indicators with "25-34" as reference), marital status (four indicators with "living together" as reference), food security (three indicators with "food secure" as reference), wealth index quintile (four indicators with "1-poorest" as reference), urbanicity (two indicators with "urban area" as reference), and region of residence (five indicators with "Central" as reference). The complex sampling survey design was taken into account in all multivariable regression models. P values are from adjusted Wald tests for interaction between year and categories of each sociodemographic characteristic.