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Neighborhood price of healthier food relative to unhealthy food and its association with type 2 diabetes and insulin resistance: The multi-ethnic study of atherosclerosis

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ABSTRACT

This study examined the association between the price of healthier food relative to unhealthy food and type 2 diabetes prevalence, incidence and insulin resistance (IR). Data came from the Multi-Ethnic Study of Atherosclerosis exam 5 administered 2010–2012 (exam 4, five years prior, was used only for diabetes incidence) and supermarket food/beverage prices derived from Information Resources Inc. For each individual, average price of a selection of healthier foods, unhealthy foods and their ratio was computed for supermarkets within 3 miles of the person's residential address. Diabetes status was confirmed at each exam and IR was assessed via the homeostasis model assessment index. Multivariable-adjusted logistic, modified Poisson and linear regression models were used to model diabetes prevalence, incidence and IR, respectively as a function of price and covariates; 2353 to 3408 participants were included in analyses (depending on the outcome). A higher ratio of healthy-to-unhealthy neighborhood food price was associated with greater IR (4.8% higher HOMA-IR score for each standard deviation higher price ratio [95% CI -0.2% to 10.1%]) after adjusting for region, age, gender, race/ethnicity, family history of diabetes, income/wealth index, education, smoking status, physical activity, and neighborhood socioeconomic status. No association with diabetes incidence (relative risk = 1.11, 95% CI 0.85 to 1.44) or prevalence (odds ratio = 0.95, 95% CI 0.81 to 1.11) was observed. Higher neighborhood prices of healthier food relative to unhealthy food were positively associated with IR, but not with either diabetes outcome. This study provides new insight into the relationship between food prices with IR and diabetes.

1. Introduction

An estimated 29 million individuals are living with diabetes, accounting for > 9% of the population (Centers for Disease Control and Prevention, 2014), and the prevalence of diagnosed diabetes has grown sharply since 2000 (Centers for Disease Control and Prevention, 2016). It is vital that we identify potential areas of intervention to reverse this trend.

Type 2 diabetes is mainly driven by obesity, and diet quality plays an important role in its development. Diets high in unhealthy, sugary, energy-dense and nutrient-poor foods are associated with an increased risk of obesity and diabetes (Brunner et al., 2008; Malik et al., 2010), while consumption of healthier foods – such as fruits and vegetables and dairy – has shown protective effects (Choi et al., 2005; Margolis et al., 2011; Mursu et al., 2014).

Unfortunately, foods that are energy dense and generally considered unhealthy tend to be the most affordable (Andrieu et al., 2006; Drewnowski, 2010; Drewnowski and Darmon, 2005; Kern et al., 2016; Monsivais et al., 2010). The price of food is associated with food purchasing decisions and consumption (Aggarwal et al., 2016; Andreyeva et al., 2010; Connors et al., 2001; Glanz et al., 1998), and thus price differences between healthy and unhealthy foods are expected to be associated with downstream effects of diet, including diabetes and insulin resistance.

Prior work that has examined prices of healthy and unhealthy foods

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and health outcomes has largely focused on the relationship between food prices and body weight. Most (Chaloupka and Powell, 2009; Chou et al., 2004; Finkelstein et al., 2014; Powell et al., 2007; Powell and Bao, 2009) but not all (Beydoun et al., 2008; Han and Powell, 2011) of these studies have shown higher healthier food prices are associated with higher BMI/obesity and/or have found that higher unhealthier prices are associated with lower BMI/obesity. However, more research is needed on the association between food prices and downstream health effects. No studies have examined food price association with type 2 diabetes and only a few studies have linked food prices directly to insulin resistance. Those studies focused primarily on metropolitan-area fast-food prices (hamburger, pizza, fried chicken) (Duffey et al., 2010; Meyer et al., 2014; Rummo et al., 2015). Duffey et al. (2010) found metropolitan area prices inversely associated with insulin resistance (Duffey et al., 2010), while Rummo et al. (2015) found no association (Rummo et al., 2015) and Meyer et al. (2014) found associations only among less advantaged residents (Meyer et al., 2014). No work to date has examined food prices at stores nearby residents and examined associations with type 2 diabetes and insulin resistance.

This study spatially linked participants from a large multi-ethnic sample to nearby supermarkets to examine associations between neighborhood food price and type 2 diabetes prevalence, type 2 diabetes incidence and insulin resistance.

2. Methods

2.1. MESA data

This study utilized data gathered by the Multi-Ethnic Study of Atherosclerosis (MESA). The MESA is a population-based longitudinal cohort study of ethnically diverse adults aged 45–84 years (Bild et al., 2002). Individuals were recruited from six sites across the United States: Bronx/Upper Manhattan, NY; Baltimore City and Baltimore County, Maryland; Forsyth County, North Carolina; Chicago, Illinois; St. Paul, Minnesota; and Los Angeles County, California. The first examination was conducted in 2000–2002 and four examinations occurred during 10 years of follow-up. Food prices were only available concurrent to exam 5, thus this study only included participants who completed exam 5 (April 2010–January 2012). Participant characteristics for the incident diabetes analysis were gathered from exam 4 (which occurred five years earlier: 2005–07, considered the “baseline” in this analysis) while exam 5 was used for all other analyses.

2.2. Outcomes - diabetes and insulin resistance

Type 2 diabetes status was based on the 2003 American Diabetes Association criteria, defined as fasting glucose ≥ 126 mg/dl and/or use of antidiabetic medications (ADA Expert Committee, 2003). Prevalent type 2 diabetes at exam 5 was defined as meeting the diabetes criteria at any of the five examinations. Incident type 2 diabetes at exam 5 was defined as meeting the diabetes criteria at the time of exam 5 with no evidence of diabetes at any prior exam.

Fasting glucose was measured by rate reflectance spectrophotometry using thin-film adaptation of the glucose oxidase method on the Vitros analyzer (Johnson & Johnson Clinical Diagnostics, Rochester, NY). Insulin resistance at exam 5 was measured according to the homeostasis model assessment index of insulin resistance (HOMA-IR). This index is well correlated with measures from the gold-standard hyperinsulinemic clamp and is calculated as (Matthews et al., 1985):

$$\text{HOMA} - \text{IR} = \frac{\text{Fasting glucose}\left(\frac{\text{mmol}}{\text{L}}\right) \times \text{Fasting insulin (in microunits per liter)}}{22.5}$$

A log transformation was used to reduce skewness of the distribution and created a normal distribution of values for use in multivariable analyses.

2.3. Covariates

Other MESA person-level data included in this study were: diet (see details below), age (continuous), sex, race/ethnicity (Caucasian, Chinese-American, African-American, Hispanic), family history of diabetes, smoking status (never, former, current), education level (high school diploma, GED, or less; some college, technical or associates degree; bachelor's degree or higher), income/wealth index (an ordinal measure ranging from 0 to 8 based on the combination of income level and ownership of four assets: car, home, land, and investments), and physical activity (measured as total hours of physical activity per day; operationalized into tertiles for modeling).

2.4. Price data

Data on food prices were obtained from Information Resources Inc. (IRI), a market research group that monitors prices of 299 consumer packaged goods sold in large chain supermarkets and superstores across the U.S. (Bronnenberg et al., 2008; IRI, 2015a, 2015b). Twenty-nine parent companies owned 100 supermarket companies in our study area. Among those, 8 parent companies (that owned 28 companies) did not agree to release their stores' data and no further information was available for those companies. Data used in this study were from 794 stores located in 11 states (including Washington DC), 72 counties, and 757 census block groups. Data years were 2009–2012.

Nine food/beverage product categories were selected to serve as proxies for either healthier or unhealthier foods. Because data for fresh fruits and vegetables were not available, refrigerated products were selected in order to roughly approximate costs of fresh fruit and vegetable spoilage and storage/distribution, and proxy fresh produce. Healthier food was represented by dairy (refrigerated milk, yogurt, cottage cheese), fruits and vegetables (frozen vegetables, and fresh orange juice). While the healthfulness of orange juice is questionable, the product was chosen to represent healthier foods due to its high correlation with the price of fresh oranges (Morris, 2011) not for its own nutritional value. Unhealthier food was represented by packaged, highly processed, long-shelf life products: soda, sweets (chocolate candy, cookies), and salty snacks.

The primary exposure of interest was the price of healthier foods relative to unhealthy foods, which was operationalized as the ratio of the average price per serving of healthy food divided by the average price per serving of unhealthy food and referred to as the healthy-to-unhealthy price ratio. The price of healthy foods and unhealthy foods were also modeled separately as secondary exposures of interest. Average prices of healthy and unhealthy foods were calculated using weights for each product class based on national consumption estimates (i.e., food types – e.g., fruits and vegetables – that are consumed more received larger weights) and converted to z-scores. A one unit change in the z-scores for the price ratio were equivalent to a 14% change in the price of healthy food relative to unhealthy food while a one unit change in the z-scores for healthy and unhealthy foods represented differences of $0.04 and $0.03 per serving, respectively. A sensitivity analysis which calculated overall healthy and unhealthy food prices using equal weights for each product class (e.g., dairy) was also performed and model results were similar to the results using the original weighting methodology.

2.5. Other data sources

US Census data came from the American Community Survey (ACS) 2007–2011. Geographic regions (Northeast, Midwest, South, West) and population density were assigned to each participant. A neighborhood block group SES index was created using six variables representing wealth and income, housing value, education, and managerial or professional occupations, and was operationalized as a single continuous measure as described by Diez-Roux et al. (Diez Roux et al., 2001).