Determinants of dietary intake and consequences of away-from-home food consumption

Kiyah J. Duffey

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Nutrition.

Chapel Hill
2009

Approved by,
Barry M. Popkin, PhD
Penny Gordon-Larsen, PhD
David Guilkey, PhD
Anna Maria Siega-Riz, PhD
Yan Song, PhD

ABSTRACT

Kiyah J. Duffey: Determinants of dietary intake and consequences of away-from-home food consumption
(Under the direction of Barry M. Popkin, PhD)

Dietary intake is a complex and multidimential behavior which has clear associations with many adverse health outcomes, including obesity. Away-from-home foods have received considerable attention as modifiable determinant of weight gain and a target for obesity prevention efforts. However, epidemiologic evidence of a link between away-from-home eating and weight gain is mixed, which may result from differences in the definition of away-from-home food or discrepancies in analytic methods. Furthermore, although a variety of individual-level determinants of away-from-home eating specifically, and dietary intake in general, have been explored, direct associations between intake and food price are understudied.

Our research addresses these substantive gaps in the literature, providing both methodological and substantive contributions to the field, by investigating the direct effect of change in food price on consumption, refining the definition of and differentiating between sources of away-from-home food (i.e. sit-down style restaurants versus fast food outlets), and examining the long-term health consequences of frequent away-from-home eating. These analyses were conducted using data from the Coronary Artery Risk Development in Young Adults Study, a 20-year prospective longitudinal cohort of 5,115 young adults. Community food prices were linked to detailed diet and health data by residential location over the full

20-year period. We report that food and beverage price seems to be an important determinant of dietary behavior: price changes were significantly associated with changes in consumption, total energy intake, body weight, and measures of insulin resistance over a 20-year period. In addition, we show important independent consequences of frequent restaurant versus fast food consumption on subsequent body weight, cholesterol levels, and measures of insulin resistance.

In summary, this research makes significant contributions to the field by advancing our understanding of the influence of food price on consumption behavior and identifying the differential effects of restaurant versus fast food consumption on health. Combined, these results have important implications for the creation of effective educational campaigns, obesity interventions or prevention efforts, and state and national nutrition policies.

This work is dedicated to:

My parents, who took great risks in the hopes that their children might have different opportunities and experiences than they did. I am eternally grateful for their support and their courage;

The women of Mere Point, who continue to encourage me, from across great distances, to become the person I am meant to be;

Little Chef, who has reinvigorated me with a sense of purpose;

and Tim, whose devotion, sense of humor, and thirst for adventure has taken me places I would dare not go alone. May I one day return the favor.

LIST OF TABLES

LIST OF FIGURES

BMI   Body mass index

C2ER   Council for community and Economic research

CARDIA Coronary Artery Risk Development in Young Adults

CI   Confidence interval

COL   Cost of living

CPI   Consumer price index

EU   Exercise units

FFQ   Food frequency questionnaire

HDL-C   High-density lipoprotein cholesterol

HOMA-IR Homeostatic model assessment insulin resistance score

HS   High school

kcal   kilocalorie

LDL-C   Low-density lipoprotein cholesterol

MEM   Marginal effect model

MSA   Metropolitan statistical area

p   p-value

SD   Standard deviation

SE   Standard error

T2DM   Type II Diabetes Mellitus

TV   Television

US   United States

I. Introduction

A. Background

        Obesity and its associated co-morbidities are major public health concerns, and while the multifactorial etiology of obesity is not well understood, relationships between away-from-home food consumption, sweetened beverages, and obesity have been hypothesized. Away-from-home eating is cited as a modifiable factor determining weight gain and obesity, and is thus viewed as a potential target for obesity prevention efforts. While the contribution of away-from-home foods to overall total energy, added fat, and refined sugar intake provide plausible mechanisms by which consumption might lead to greater weight gain, epidemiological evidence of this effect is sometimes mixed. Inconsistent findings could be the result of discrepancies in analytical techniques, which highlights the need to explore alternative methods for evaluating the relationship between away-from-home food consumption and subsequent health outcomes. Alternatively, the observed inconsistencies may be the result of differential definitions of away-from-home food, namely that fast food and other away-from-home options are not examined independently of one another.

        A variety of individual-level determinants of sweetened beverage and away-from-home food consumption, most notably sociodemographic factors, have been explored, but largely missing from the literature on this topic is a direct examination of the role of food and beverage price. To date, research in this area has relied largely on aggregate measures of

food price, food availability, or food intake to estimate individual-level effects, which requires the acceptance of numerous assumptions that may not be valid (i.e. that availability is equal to consumption). Furthermore, attempts to examine the indirect effect of food price on health outcomes, such as weight, have been accomplished using theoretical economic models, unassociated with individual-level outcome data. As a result, we have little empirical evidence of the relationships between food and beverage price, consumption, and health outcomes.

In this study, we capitalize on the opportunity to explore the economic determinants of food and beverage consumption, as well as the associated health consequences of beverage and away-from-home food intake in a sample of US adults. Our analyses were conducted using data from the Coronary Artery Risk Development in Young Adults (CARDIA) Study, a 20-year longitudinal cohort of 5,115 young adults. Detailed diet and health data for each CARDIA participant were linked to community food prices by residential location over time. This research fills important gaps by quantifying the influence of food and beverage price on consumption and by broadening our understanding of the role of away-from-home food consumption as a potential causal mechanism of obesity and its associated co-morbidities.

B. Research Aims

The overarching goal of these analyses was to improve our understanding of the relationship of away-from-home food consumption with obesity, insulin resistance, and metabolic outcomes, with particular attention paid to evaluating the influence of price on these relationships. Specific aims were as follows:

1) Examine the relationship between price consumption, and selected health outcomes.

      a. Determine the changes in price of beverages (low- and whole-fat milk, fruit juice, soda) and away-from-home foods (pizza and hamburgers) over a 20-year period. We hypothesized a decline in the real price of all foods and beverages, with a more pronounced decrease in the price of soda compared to all other foods.

      b. Determine the relationship between changes in food and beverage price with changes in consumption, total energy intake, weight, and glucose status over a 20-year period. We hypothesized that increased prices would be associated with declines in consumption, specifically that as the price of a given food (beverage) increased daily energy obtained from that food (beverage) would decrease. Furthermore, we hypothesized that increases in the price of soda, pizza, and hamburgers would be associated with declines in total energy intake, weight gain, and metabolic outcomes over the 20-year period. We used log-log models of elasticity to determine the effect of percent change in price on percent change in each outcome across each of the six food and beverage groups of interest.

2) Determine the longitudinal relationship between the frequency of away-from-home eating with weight and metabolic outcomes, and to further determine if these relationships differ for fast food versus sit-down style restaurant consumption. We hypothesized that an increased frequency of consuming fast food would be positively associated with weight and metabolic outcomes over time while an increased frequency of consuming restaurant foods would not. We used fixed-effect repeated measures conditional regression models to examine these

relationships over a 13- year period (1992-2006). In addition to being able to handle

longitudinal data on subjects with varying numbers of unequally spaced observations, these

models adjust for potential confounding from both measured and unmeasured (or

unobserved) time invariant characteristics that are not modifiers of the relationship of

interest.

II. LITERATURE REVIEW

A. Obesity is a Major Public Health Concern

The prevalence of obesity has risen dramatically in the past few decades among all race, gender, and age groups (Flegal, Carroll et al. 2002; Hedley, Ogden et al. 2004; Ogden, Carroll et al. 2006) and now affects nearly one-third of the American adult population with a full 66% overweight or obese (Ogden et al. 2006). Worldwide, the number of overweight and obese individuals far surpasses the number that are malnourished (Popkin 2008). Among adolescents (aged 12-19 years) there was a near tripling of the prevalence of overweight from 5% through the 1980s (Flegal 2005) to 16% in 2006 (Ogden et al. 2008). Anthropometric measures, particularly BMI (Freedman et al. 2004), are positively correlated through young and middle adulthood (Serdula et al. 1993; Gordon-Larsen et al. 2004), and weight loss later in life is not consistently associated with improvements in risk factors (Douketis et al. 2005).

Furthermore differences in the rates of obesity and obesity related health outcomes exist between ethnic groups (McTigue et al. 2003; Freedman et al. 2005; Ogden et al. 2007) and by socioeconomic status (Lillie-Blanton et al. 1996; Williams 1997; Gordon-Larsen et al. 2003; Borders et al. 2006). For example, African Americans and other minority groups experience higher rates of obesity (Sobal and Stunkard 1989; Ball and Crawford 2005), tend to experience obesity incidence at younger ages (McTigue et al. 2003), and are at increased risk for developing obesity related health outcomes at lower BMI levels (Gordon-Larsen et

al. 2002) compared their White counterparts. Many of these differences are likely mediated by socioeconomic status (Robert and Reither 2004).

Obesity is a complex disease associated with numerous adverse health outcomes (Pi-Sunyer 1993; NTFPTO 2000; Uauy and Diaz 2005; Mainous, Diaz et al. 2008) including type 2 diabetes, cardiovascular disease, and some cancers, and to increased mortality overall (Flegal et al. 2005). Further associations have been made to economic losses from both direct and indirect costs (Must et al. 1999), and reductions in psychological health and quality of life (Kruger 2007; Gray and Leyland 2008; de Wit et al. 2009). There are myriad pathways leading to the development of obesity with contributions from biological, behavioral, social, and environmental determinants. Nonetheless, the epidemic of obesity that we currently face is predominantly behaviorally, socially, or environmentally based due to the slow rate of genetic mutation compared to the time frame over which the epidemic has emerged. We focused our efforts on examining the role of these potential contributors, specifically the consumption of low-cost calorically dense foods and beverages, in the US obesity epidemic.

B. Co-morbidities of obesity: diabetes and the metabolic syndrome

Obesity is considered a salient and modifiable risk factor of type 2 diabetes (T2DM) (Cassano et al. 1992; Goran et al. 2003; Schienkiewitz et al. 2006; Mayer-Davis 2008), and over the last several decades the trend in T2DM has paralleled the rise in obesity rates (Centers for Disease and Prevention 2004; Ogden, Yanovski et al. 2007). A recent meta-analysis illustrates that body mass index is significantly associated with incident diabetes among adults (Vazquez et al. 2007). Obesity affects both insulin sensitivity and insulin

secretion: in an obese state, adipose tissue releases increased amounts of non-esterified fatty acids, hormones, pro-inflammatory cytokines, and other factors which ultimately act to limit the amount of glucose uptake by muscles (Felber and Golay 2002). When this is further accompanied by dysfunction of the pancreatic islet beta-cells – the cells that produce insulin – failure to control blood glucose levels (diabetes) arises (Kahn et al. 2006). Insulin sensitivity, an important correlate of plasma lipoproteins (Laakso et al. 1990; Kekalainen et al. 2000), is often cited as the common link between obesity and multiple metabolic risk factors (Reaven 1997), however there is recent recognition that cytokines secreted by adipocytes (present in overabundance among overweight and obese individuals) may underly the pathophysiology of both insulin resistance and the metabolic syndrome, a cluster of disorders characterized by central obesity and any two of the following: hypertension, hypertriglyceridemia, reduced high-density lipoprotein cholesterol (HDL-C), or impaired fasting glucose (Alberti et al. 2005).

Independent of its relationship to insulin resistance or T2DM, obesity is a risk factor for several other metabolic outcomes. Overweight and obesity account for an estimated 66% of the increased risk of hypertension in some populations (Garrison et al. 1987; Huang et al. 1998), and body mass index, waist circumference, and waist-to-hip ratio measures have all been shown to be predictors of hypertension (Dyer et al. 1999; Guagnano et al. 2001; Zhu et al. 2002). The link between dyslipidemia, one of the most common disorders associated with obesity, and obesity is not well understood, but evidence suggests that insulin resistance may be the underlying mechanism (Ginsberg et al. 2006; Reaven 2008): insulin resistance

diminishes the inhibitory effect of insulin on the release of free fatty acids from adipose tissue.

C. The changing food environment

Although the field of geography has long recognized the connection between people and their environment, only in recent decades has the field of public health turned its attention toward the physical food environment as a potential determinant in shaping individual behaviors associated with disease development. With respect to dietary patterns and obesity, understanding the food environment as it relates to the availability of food stuffs is particularly salient as convenience and availability are important predictors of food habits among adolescents (French, Story et al. 2001; Story, Neumark-Sztainer et al. 2002; Neumark-Sztainer, Wall et al. 2003; Boutelle, Fulkerson et al. 2007) and adults (Glanz, Basil et al. 1998; Inglis, Ball et al. 2005). The food environment might also directly affect individual dietary behaviors, in particular patterns of away from home food eating, through targeted placement of food stores (Block, Scribner et al. 2004; Austin, Melly et al. 2005).

At the community-level, differences in the food environment between racially and economically segregated neighborhoods may explain some of the differences in health outcomes, such as obesity, that are observed even after accounting for individual-level factors (Pickett and Pearl 2001; Robert and Reither 2004). Numerous studies have demonstrated differential access to food places, including supermarkets, smaller grocery stores, restaurants and fast food places, by neighborhood deprivation (Cubbin, Hadden et al. 2001; Cummins, Stafford et al. 2005), ethnic composition (Block, Scribner et al. 2004;

Moore and Diez Roux 2006), and area-level wealth (Morland, Wing et al. 2002; Reidpath, Burns et al. 2002).

D. Away-from-home eating has important relationships with many aspects of health

1. Determinants of away-from-home eating

In the past few decades there have been dramatic shifts in the patterns of away-from-home food eating among adolescents and adults. Daily calories are more frequently coming from energy-dense nutrient poor foods and snacks (Flegal et al. 2005) in larger portion sizes (Nielsen and Popkin 2003). Additionally, a growing number of meals are being consumed away-from-home (Zizza et al., 2001; Nielsen et al., 2002), with these meals providing a greater proportion of total daily calories (French et al. 2001; Nielsen et al. 2002; Jeffery and Utter 2003). Although rates of away-from-home consumption have increased among all age-gender groups, the greatest change was observed among males aged 18-39, who consumed 39% of their daily calories away-from-home (Guthrie et al. 2002), accounted for in large part by salty snacks, soda/fruit drinks, Mexican food, and pizza (Guthrie et al. 2002). Associations with frequent away-from-home eating have been made to younger age, lower income, fewer years of education, and minority race in some (Satia, Galanko et al. 2004; Schmidt, Affenito et al. 2005) but not all studies (Kant and Graubard 2004).

2. Association with obesity and metabolic outcomes

The parallel trends of increased consumption of food away-from-home (in particular fast food) and obesity beginning in the 1980s provide ecological-level evidence of a link between the two. Associations between away-from-home eating and overweight and obesity

9

have also been observed at the individual level (French et al. 2001; Paeratakul et al. 2003). Frequent consumption of restaurant and fast foods has been associated with higher BMI (Bowman and Vinyard 2004; Lin et al. 2004) and body fatness (McCrory et al. 1999) in cross sectional studies, although in some cases these associations were observed in females but not males (Jeffery and French 1998) or high income versus low income females only (Lin et al. 2004). Increased away-from-home food consumption is also associated with greater weight gain (French et al. 2000; Duffey et al. 2007; Rosenheck 2008) and insulin resistance (Pereira et al. 2005), evidence of a potentially causal relationship between away-from-home eating and adverse metabolic outcomes.

3. Association with dietary patterns and diet quality

One proposed mechanism by which away-from-home eating may be associated with weight gain is through its impact on diet (Prentice and Jebb 2003). Away-from-home food tends to be higher in total calories, total & sat fat, and refined carbohydrates (Lin et al. 1999; Cavadini et al. 2000) and tends to be served in significantly larger portion sizes (Young and Nestle 2002; Nielsen and Popkin 2003; Smiciklas-Wright et al. 2003; Diliberti et al. 2004) than foods consumed at home. Persons who regularly consume food away-from-home have diets characterized by greater energy density (Bowman and Vinyard 2004), higher total energy intake per day (McCrory et al. 1999; Bowman and Vinyard 2004) and per eating occasion (Guthrie et al. 2002), a higher percent of energy from fat (French et al. 2001; Schmidt et al. 2005), and increased consumption of carbonated soft drinks (Paeratakul et al. 2003), Futhermore, their diets tend to be characterized by lower intakes of fiber (Clemens

10

1999; Guthrie, Lin et al. 2002), Vitamins A and C (Paeratakul et al. 2003), and fruit,

vegetables and dairy products (Paeratakul, Ferdinand et al. 2003; Satia, Galanko et al. 2004).

Evidence suggests that tracking of overall diet quality, dietary preferences, and

macronutrient intake occurs between young adulthood and adulthood (Dunn et al. 2000;

Bertheke Post et al. 2001), yet there is a relative absence of longitudinal studies investigating

long-term patterns of away-from-home consumption and select few have examined the

effects of frequent away-from-home eating and energy intake over time (French et al. 2000;

Schmidt et al. 2005). Furthermore, a vast majority of studies do not differentiate between fast

food restaurants and more traditional, family-style dinning places, which may be

differentially associated with long-term diet behaviors or weight gain (Duffey et al. 2007)

and only two have examined the modifying effect of race (Thompson et al. 2004; Pereira et

al. 2005).

Because of the link between diet patterns and obesity (McCrory et al. 2000;

Quatromoni et al. 2002; Koh-Banerjee et al. 2003), there is a need for better understanding of

the relationship between away-from-home eating and diet quality as well as identification of

modifiable predictors of these behaviors. In the research described herein, we took advantage

of a large ethnically and economically diverse longitudinal sample of US adults. These data

contain information on away-from-home food consumption from both fast-food and sit-down

style restaurants, as well as detailed measures of multiple health outcomes. Thus, we were

able to more fully investigate the differential effects of these two food sources, their

11

association with multiple health outcomes, and add scientific knowledge concerning these important relationships.

E. Food price as a determinant of diet and predictor of health

1. Price is a factor in food choice

Individual food choice is influenced by numerous factors including taste, economy (food price and income), convenience (opportunity costs), health (including weight) and variety (Finkelstein et al. 2004; Cardello and Garr (In Press) 2009), in addition to the powerful influences of marketing, and peer/social norms (e.g. (Glanz et al. 1998; Booth et al. 2001; Story et al. 2002; Laraia et al. 2004; Popkin et al. 2005)). Although taste, economy (i.e. cost) and convenience consistently rank highest, some studies suggest that there are important differences by socioeconomic status (Mooney 1990; Kamphuis et al. 2007). The poor are typically more sensitive to food price changes and there is a positive effect between income and away from home food expenditures (Guo, Popkin et al. 1999; Stewart, Blisard et al. 2004; Ng, Zhai et al. 2008).

The relationship between price and consumption is likely mediated by accessibility. Urban dwelling individuals have been shown to pay considerably more for the same foods purchased in their smaller, community stores compared to suburban dwelling residents who can purchase from large chain supermarkets (Chung and Myers 1999). Larger supermarkets tend to offer a greater variety of nutritious food options at lower cost (Chung and Myers 1999; Eisenhauer 2001), but these stores have largely moved out of urban areas (Nayga and Weinberg 1999). Differences in the presence of food stores, cost of purchasing healthier food

items at these food places, and other individual-level factors, such as lack of transportation, may substantially limit the opportunity for healthy eating among less wealthy, minority individuals.

2. *Food cost and diet quality*

Current dietary recommendations emphasize consumption of fresh fruits and vegetables, whole grains, and lean protein, encouraging limited consumption of items like sugar-sweetened beverages and fast food. However, in the US and elsewhere, it has been documented that these healthier foods tend to cost more (Drewnowski, Darmon et al. 2004; Darmon, Darmon et al. 2005; Drewnowski and Darmon 2005; Drewnowski and Darmon 2005; Drewnowski, Monsivais et al. 2007) and that diet quality is often a function of social class (Darmon and Drewnowski 2008). Wealthier consumers tend toward more varied, healthier, and higher quality diets (e.g. (Irala-Estevez, Groth et al. 2000; Martikainen, Brunner et al. 2003)) compared to lower-income consumers (e.g. (Smith and Baghurst 1992; Hulshof, Brussaard et al. 2003)). Regular adherence to healthier diets has also been shown to cost more (Darmon et al. 2005; Schroder 2006) and to be inversely associated with BMI (Schroder 2006; Murakami et al. 2007).

3. *Individuals' responses to food price are not static*

Food price represents a modifiable factor that could be targeted for population-level interventions and nutrition policies (Horgen and Brownell 2002). Multiple strategies have been used to study the relationship between changes in price and consumption. Using linear modeling to predict food purchasing decisions given budget constraints, Darmon et al. found

that strengthening cost constraints placed on foods resulted in a reduction in the proportion of energy contributed from fruits, vegetables, meats and dairy products, and increased that from cereals, sweets and added fats (Darmon et al. 2002). The overarching result was a decrease in diet quality. Several small-scale quasi-experimental studies demonstrated that price reductions on healthier, low-fat food options in vending machines and in school and workplace cafeterias were associated with increased sales of those food items (French, Storey et al. 1997; French 2003). A comparison of three price reductions of 10%, 25% and 50% on lower-fat snacks in high school vending machines resulted in an increase in sales of 9%, 39% and 93%, respectively, compared with usual price conditions (French, Jeffery et al. 2001).

Other studies have shown more direct effects of changes in price on consumption. City-wide taxes on high-fat dairy products was associated with city-wide decreases in the sales of these items in the US (Chouinard et al. 2007), and price increases were predicted to result in a decreased demand, and consumption, of dairy products in the European Union (Bouamra-Mechemache et al. 2008). Finally, experimental laboratory studies (Epstein et al. 2006; Epstein et al. 2007) have shown that changes in food price can influence the purchase of low- and high-energy density foods.

4. Associations of price with consumption and weight

Another, albeit considerably smaller, body of research has utilized econometric modeling strategies (Schroeter et al. 2008) or indirect price estimates (Schroder 2006) in an attempted to examine the ways in which price fluctuations effect subsequent health outcomes. Adherence to the Mediterranean Diet Score and the Healthy Eating Index resulted

in significantly higher daily food cost ($1.50- $1.75/day), but was also associated with having a lower BMI (Schroder 2006). Some researchers, however, warn that there is too little evidence to support proposed price changes as a means for improving health outcomes (Finkelstein et al. 2004), particularly if alternative purchasing options are not also considered (Huang 1997; Caraher and Cowburn 2005). At least one empirical analysis demonstrated that increasing the cost of away-from-home food could result in increased body weight, depending on the concurrent price changes to alternative (i.e. replacement) foods (Schroeter et al. 2008).

Generally, estimation studies on the effect of price on diet and health outcomes use household or aggregate (county, state, or national level) expenditure data converted to estimates of average per capita food spending. Thus, the major limitation of these studies is that they do not directly link an individual's food costs to that individual's dietary intake or subsequent health experience, nor can they account for changes in individual or family-level income. In this research, we used price, consumption, and health data that were directly measured at the level of the individual to fill these important gaps in the literature.

F. Current gaps in knowledge and research needed

Through this research, we were able to fill important gaps in our understanding of the economic determinants of decisions to consume away-from-home foods, and the consequences of such decisions on subsequent health outcomes. Although plausible mechanisms for the role of away-from-home food consumption in weight gain and other metabolic outcomes exist, epidemiologic studies have often produced inconsistent results.

Such inconsistencies could result from methodological limitations, including incomplete control for unmeasured confounding factors or failure to account for the differential associations of various types of away-from-home foods (i.e. fast food versus sit-down style restaurant consumption).

Our research addresses these methodological concerns and adds important insight to the health implications of frequent away-from-home eating. Furthermore, we fill an important gap in the literature of determinants of food and beverage purchasing behaviors by examining long-term changes in the relationship between food price and consumption at the individual-level. By deepening our understanding of the extent to which prices influence intake decisions, and the degree to which various away-from-home food sources are related to weight and metabolic health outcomes we can better inform future health policy and intervention strategies aimed at obesity prevention.

III. Methods

A. Description of the population & study sample

1. Overview of study design and sampling

The Coronary Artery Risk Development in Young Adults (CARDIA) Study was initiated to examine the development of heart disease during adulthood. At baseline (1985-86) the sample included 5,115 participants, aged 18-30, who were randomly selected from four US cities: Birmingham AL, Chicago IL, Minneapolis MN, and Oakland CA. Recruitment procedures were similar, though not identical, between the four locations and have been described in detail elsewhere (Hughes et al. 1987). Briefly, participants were randomly selected and recruited by telephone from census tracts in Minneapolis and Chicago, by telephone exchanges in Birmingham, and from lists of Kaiser-Permanente health plan membership in Oakland. Each of the centers was successful in recruiting sex, race (black and White), education and age (18-25 and 25-30yrs) balanced baseline samples. Follow-up interviews were conducted at Exam years 2 (1987-1988), 5 (1990-1991), 7 (1992-1993), 10 (1995-1996), 15 (2000-2001), and 20 years (2005-2006) post baseline with retention rates of 90%, 86%, 81%, 79%, 74% and 72% respectively. A complete listing of exam components can be found at the CARDIA website (CARDIA 2009).

2. Exclusions

The sample utilized for all aims of this analysis excluded female participants who were pregnant at the time of interview because changes in dietary intake, weight, and/or health status during pregnancy are not the focus and do not necessarily reflect permanent changes in behavior or the outcomes of interest. By outcome, participants (or participant observations in longitudinal models) were excluded if they had the outcome of interest at baseline (i.e. those who were obese at baseline in models examining incident obesity), or were taking medication designed to effect the outcome (i.e. those taking cholesterol lowering medication in models examining the incidence of high Low-density lipoprotein cholesterol [LDL-C]). Specific sample sizes are described in greater detail for each analysis.

B. Measurement of key variables

1. Away-from-home eating and dietary intake

Frequency of fast food and restaurant consumption was assessed using two separate questions. To determine fast food consumption, participants were asked "How many times in a week or month do you eat breakfast, lunch, or dinner out in a place such as McDonald's, Burger King, Wendy's, Arby's, Pizza Hut, or Kentucky Fried Chicken?" To estimate consumption at non-fast food restaurants, participants are asked "How many times in a week or month do you eat breakfast, lunch, or dinner in a restaurant or cafeteria (eat-in or take out)?" All responses were calculated to reflect a per week consumption frequency.

Dietary intake was assessed using a semi-quantitative, interviewer administered, validated (Slattery et al. 1994) Diet History Food Frequency Questionnaire. Details

pertaining to the development of the questionnaire have been described elsewhere (McDonald, Van Horn et al. 1991; Hilner, McDonald et al. 1992). The quantitative diet history was administered to all participants at baseline (Exam year 0), Exam year 7, and Exam year 20. It asked participants to report the type, amount, and frequency of foods eaten during the past month and probed further into preparation methods, including specific fats used in cooking. A selection of additions commonly made to foods while cooking were also included to obtain a more accurate estimate of total calories, fat, and carbohydrates in the diet. From the diet history, food groups were created based on typical consumption behavior. For example, hamburgers from a fast food restaurant were included in the "sandwiches/ hamburger/ fast food" food group rather than the component parts of the hamburger being included in several food groups (i.e. "Grain", "Beef", and "Leafy green vegetables"). Estimates of daily intake of energy, macro (i.e. protein), and micronutrients (i.e. calcium) were associated with each food group.

2. Anthropometric variables

Anthropometric measures were obtained using trained technicians using equipment which was calibrated weekly with participants standing and dressed in light clothing without shoes. Bodyweight was measured to the nearest 0.2 kg using a balanced beam scale, height was measured to the nearest 0.5 cm using a vertical ruler, and waist size with a tape in duplicate to the nearest 0·5 cm around the minimum abdominal girth. BMI was calculated as weight (kg) divided by height (m^2). At each Exam year, we generated dichotomous indicator variables to identify individuals as underweight (BMI <18.5 kg/m^2), normal weight (BMI

18.5-29.9 kg/m^2), overweight (BMI 25-29.9 kg/m^2) or obese (BMI ≥30 kg/m^2) according to the National Institutes of Health clinical cut points (National Institutes of Health 1998).

3. Biochemical measurements

Blood samples were drawn following an overnight fast using a Vacutainer containing EDTA. Cells were separated from plasma, which was transferred into airtight vials and stored until shipment to the University of Washington Northwest Lipid Research Laboratories (Seattle). Total cholesterol and triglycerides were measured by enzymatic methods within 6 weeks of collection. HDL-C was assayed after dextran sulfate-magnesium precipitation (Warnick et al. 1982), and LDL-C was estimated from the Friedewald equation (Friedewald 1972). Glucose was measured using hexokinase coupled to glucose-6-phosphate dehydrogenase, as was serum insulin with an immunoassay (Linco Research Inc, St Louis, Missouri). The homeostasis model of insulin resistance (HOMA-IR) was calculated as [glucose (mmol per liter) X insulin (µU per liter)]/22.5](Matthews et al. 1985).

4. Food and beverage prices

Food price data were compiled by the Council for Community and Economic Research (C2ER, formerly the American Chamber of Commerce Research Association, (C2ER 2008)). Conducted quarterly for approximately 300 US communities, this survey provides price variables for more than 60 consumer goods and services complied across participating metropolitan and non-metropolitan areas. Grocery items (i.e., specific foods and beverages), fast food items, cigarette prices, and cost of living and overall price indices have been collected as part of the *Inter-City Cost of Living Index*, published quarterly since 1968. Price data were linked to CARDIA respondents temporally (based on the year and quarter of

CARDIA exam dates) and spatially (based on the respondent's residential location at each time point). Respondents for whom there was not a direct match between residential location and the city and year in which food price data were collected, prices were imputed. Using the consumer price index (CPI) we inflated prices for the particular year and quarter in which the individual diet surveys were conducted. The CPI with the index of Year 2006, quarter 3 (index=100%) was used as the baseline to inflate the nominal values for all prices, allowing for comparability in food prices over the full 20 year period.

5. Additional covariates

Non-anthropometric or biological variables relevant to these analysis include race, gender, age (in years), education (less than high school [HS], completed HS, some college, 4 or more years of college), family structure (single, married, single with children, married with children), and smoking status. Physical activity was assessed using the validated CARDIA physical activity questionnaire (Jacobs et al. 1989). Results are reported in exercise units (EU) per week. A measure of sedentary behavior, hours of TV viewing per week, was also collected.

For Aim 2, information on the cost of living (COL) was obtained for all participants (C2ER 2008). The COL index measures differences in the cost of consumer goods and services, excluding taxes and non-consumer expenditures. Collected on more than 50,000 prices covering 60 different items, the index is based on six component parts – housing, utilities, grocery items, transportation, health care and miscellaneous goods and services. Prices were collected quarterly by chambers of commerce, economic development

organizations or university applied economic centers in each participating urban area (C2ER

2008). As with the price data, COL was linked both spatially and temporally to each

CARDIA respondent.

IV. Increased food prices are associated with changes in diet, weight, and HOMA insulin resistance over 20 years of the CARDIA Study

A. Introduction

While policies are beginning to target factors affecting price, including taxation of foods and beverages, as a way to address obesity, diabetes, and other nutrition-related health concerns, minimal research has been done to study how these changes would impact health. Taxation has been a very effective way to reduce adult and teen smoking (Grossman and Chaloupka 1997; Chaloupka et al. 2002). In contrast, research on the role of food and beverage pricing has focused on broad ecological relationships (Cash et al. 2005; Finkelstein et al. 2008; Schroeter et al. 2008) or small experiments (French et al. 2001; French 2003; Epstein et al. 2006; Epstein et al. 2007) but has not examined direct effects on food and beverage choices in large populations or over long periods of time.

To compensate for food environments where healthy foods (i.e. fresh fruits and vegetables) tend to cost more (Drewnowski and Darmon 2005; Drewnowski and Darmon 2005), public health professionals, politicians and others have suggested that foods high in calories, saturated fat, or added sugar be subject to added taxes and/or that healthier foods be subsidized (Jacobson and Brownell 2000; Cash et al. 2005; Chouinard et al. 2007; Popkin 2008). Such measures, or a combination of these measures, could prove to have a particularly powerful impact for lower income individuals because they are typically more sensitive to

changes in food price (MacDonald and Nelson Jr. 1991; Chung and Myers 1999; Stewart et al. 2003; Stewart et al. 2004; Popkin 2008) and because lower income consumers tend to have less varied, lower quality diets compared to higher income consumers (Hulshof et al. 2003). Manipulation of food prices, through subsidies and other methods, has been a mainstay of global agricultural and food policy (Popkin 2008; von Braun 2008) employed as a means to increase availability of animal foods and basic commodities, but it has not been readily employed as a mechanism to promote public health and chronic disease prevention efforts (WHO 2000; WHO/FAO 2003; Popkin 2008).

This is beginning to change. The state of Maine currently taxes manufacturers on bottles of simple syrup and consumers on bottled soft drinks. In 2008 the state of New York proposed an 18% consumer tax on soft drinks, and other cities and states around the country are reviewing similar options as a means to promote health and raise money for underfunded health care systems. Some researchers warn that there is little evidence that a tax on these [high calorie, sugary foods] products would improve health (Finkelstein et al. 2004), particularly if alternative purchasing options (e.g. food substitutions) are not also considered (Caraher and Cowburn 2005). For instance, increases in coffee prices might be linked with reduced cream or sugar intake and increased tea intake (Huang 1997; Ng et al. 2008).

We investigate the secular trends in selected food and beverage prices and the association of these changes with consumption (also known as the price elasticity of demand), total caloric intake, weight and homeostasis model assessment- insulin resistance (HOMA-IR) over a 20-year period in the Coronary Artery Risk Development in Young

Adults (CARDIA) Study. Price elasticity of demand is defined as the measure of responsiveness in the quantity demanded for a commodity as a result of change in price of that same commodity. We used directly measured individual-level food consumption and health outcome data linked with community price data (specific to each individual's time-varying residential location at the time food consumption data were collected) to examine the relationships between price changes and changes in dietary intake and selected health outcomes.

B. Methods

1. Study population

The Coronary Artery Risk Development in Young Adults (CARDIA) Study is a multicenter, longitudinal study of the determinants and evolution of cardiovascular disease risk in Black and White young adults. CARDIA participants were drawn from one of four US cities (Birmingham, AL; Chicago, IL; Minneapolis, MN; Oakland, CA), with recruitment procedures designed to create a balanced representation of age, gender, ethnicity, and education group in each location. The baseline survey was completed by 5,115 young adults, aged 18-30. Follow-up examinations were conducted at 2, 5, 7, 10, 15 and 20 years post baseline with retention rates of 91%, 86%, 81%, 79%, 74%, and 72% respectively. Data from exam years 0, 7, and 20 were used for this study, as these are the years in which dietary data were collected. Detailed descriptions of the sampling plan and cohort characteristics are described elsewhere (Hughes et al. 1987; Friedman et al. 1988).

2. Food Prices

Food price data were compiled by the Council for Community and Economic Research (C2ER, formerly the American Chamber of Commerce Research Association, (C2ER 2008)). Conducted quarterly for approximately 300 US communities, this survey provides price variables for more than 60 consumer goods and services across participating metropolitan and non-metropolitan areas including: grocery items (i.e., specific foods, beverages), fast food items, cost of living and overall price indices, and cigarette prices. From the available price data, we selected the following beverage and food variables based on comparability with individual-level food consumption data in CARDIA: soft drink (cost for a 2 Liter (L) bottle of Coke), whole milk (cost for one-half gallon), orange juice (cost for a 6 ounce (oz) can frozen juice), hamburger (1/4 pound (lb) burger, purchased away-from-home), and pizza (12-13 inch cheese, thin crust purchased away-from-home). We also include a selection of prices of hypothesized complementary and replacement foods and beverages: beer (cost of a 6 pack, 12 oz bottles), wine (cost of a 1.5 L bottle), coffee (cost of a 1 lb can of ground coffee), bananas (cost of 1 lb), steak (cost of 1 lb., USDA choice), parmesan cheese (cost of 8 oz, grated), and fried chicken (cost of 2 pieces, thigh and drumstick, purchased away-from-home). Although we would have ideally included the price of alternative types of milk (i.e. low-fat milk) or away-from-home sandwiches (i.e. chicken sandwich) this information was not collected and thus not available to us.

We inflated prices by the consumer price index (CPI) for the particular year and quarter in which the individual diet surveys were conducted to remove the effect of inflation.

The CPI represents changes in prices of all goods and services purchased for consumption by urban households, including user fees and sales and excise taxes, but excluding income taxes (Bureau of Labor Statistics 2001). We used the CPI with the index of Year 2006, quarter 3 (index=100%) as the baseline to inflate the nominal values for all prices.

We linked price data to CARDIA respondents temporally (based on the year and quarter of CARDIA exam dates) and spatially (based on the respondent's residential location at each time point). For respondents for whom there was not a direct match between residential location and the city (defined using Metropolitan Statistical Areas (MSA) and year in which food price data were collected, prices were imputed (n = 3,503 observations (29%)). For example, if a respondent's residential location had a single matching MSA code and price data were available for the year and quarter in which the respondent was surveyed, prices from that matching MSA were assigned to the respondent. A dummy variable indicating imputed prices was included in all final models. Excluding the indicator variable, or the imputed values, did not result in significant changes in our estimates.

3. Dietary Assessment

Usual dietary intake was assessed using the CARDIA Diet History, an interviewer-administered questionnaire regarding general dietary practices followed by a comprehensive quantitative food frequency (FFQ) questionnaire. The diet history queried foods consumed over the past 28 days, and for foods consumed included follow-up questions regarding the typical serving size, frequency of consumption, and common additions (McDonald et al. 1991). Respondents were able to include foods regularly consumed but not listed on the FFQ

portion of the Diet History. The reliability and validity of the Diet History have been assessed (Liu et al. 1994).

We use three beverage and two away-from-home food categories in our analyses: whole milk (fluid milk only, not powdered, evaporated or condensed or fluid milk used in recipes), orange drinks (25-100% juice, hereafter called orange juice), soft drinks (regular, sweetened), hamburgers (sandwich, fast food) and pizza (frozen/restaurant). The groups provided the closest match to our price variables.

4. Anthropometrics and Insulin Resistance

Measured height (nearest 0.5 cm) and weight (nearest 0.1 kg) were collected by trained technicians. Fasting insulin and glucose were obtained by venous blood draw. Glucose was measured using hexokinase coupled to glucose-6-phosphate dehydrogenase. HOMA-IR score was calculated as [fasting glucose (mmol per liter) X fasting insulin (μU per liter)]/22.5] (Matthews et al. 1985).

5. Covariates

At each exam period, self-reported information on sociodemographic and selected health behaviors was collected using standardized questionnaires, including age, education (completed elementary school, 3 years high school, 4 years of high school, 3 years college, or 4 or more years of college), income (low [<$25,000 ($25K)], middle [$25,000- <$50,000 ($25-<50K)]), and high [≥$50,000]), and family structure (married, single, married with children, and single with children). Race (black vs. white) and gender were verified at each follow-up exam. Physical activity, in exercise units (EU) per week, was assessed using the

CARDIA physical activity questionnaire (Jacobs et al. 1989). Information on the cost of living (COL) was obtained from C2ER and spatially and temporally linked to each respondent via their residential location. The COL index, which measures differences in the cost of consumer goods and services, excluding taxes and non-consumer expenditures, is based on six components – housing, utilities, grocery items, transportation, health care and miscellaneous goods and services. Data for the index were collected on more than 50,000 prices covering 60 different items by chambers of commerce, economic development organizations or university applied economic centers in each participating urban area (C2ER 2008).

6. Statistical Analaysis

All analyses were completed in Stata 10 (Stata Corp, College Station, TX). Descriptive statistics of beverage prices, kcal per person and per consumer, and percent consuming each food and beverage group were compared across the three exam periods, with statistical significance set at the $p < 0.05$ level (two-tailed test). Pooled values were calculated to provide an estimate of the average price and consumption over time.

Our overarching goal was to examine (1) the price elasticity of demand, or the ratio of a percent change in price to the percent change in consumption, for selected beverages and away-from-home foods and (2) the effect of income on consumption. For analysis of price elasticity, separate estimations were made for (1) the probability of consuming a given food or beverage and (2) the amount of food consumed, thus resulting in estimates conditioned on consuming (Haines, Guilkey et al. 1988). These two-part marginal effect models (MEM) are

useful for eliminating bias when examining outcomes where there are large proportions of zero values (i.e. non-consumers), as was the case in our sample, that do not represent missing data.

We pooled data across three exam years and robust standard errors were used to correct for multiple observations on individuals and possible heteroscedasticity. The two-part model includes a probit model using maximum likelihood estimation in the first step to estimate the probability of consuming a given food or beverage. The second part was a conditional log-log ordinary least square regression model on only the subsample of those who consumed that food or beverage. Both models were clustered on the individual, to correct standard errors for multiple observations. These two values were then multiplied resulting in an estimate that is a weighted mean of the effect of changes in price on changes in consumption for the full sample.

The two parts had the same specifications: control variables included age, gender, race, family income, highest level of education completed, family structure, logged prices of selected complementary and replacement foods (specified for each food/beverage model separately), a logged value for the COL index, an indicator variable for having imputed price data, and time indicator variables for exam years 0 and 7. We tested and did not find statistically significant interactions between logged price values and time, and logged price values with income (likelihood ratio test $p > 0.10$). The two parts were estimated separately before deriving unconditional elasticities and their bootstrapped standard errors (using 1000 replications).

We examined own-price elasticity, defined as the percentage change in consumption (amount demanded) associated with a percentage change in price. This value should be negative, because quantity demanded, and consumed, should fall with rising prices. In addition, we examined cross-price elasticity, the percentage change in consumption (amount demanded) of the first good associated with a percentage change in the price of a second good. Foods with positive cross-price elasticities are considered replacement or substitute foods, while those with negative values are considered complements. We were unable to estimate income elasticity, as income was represented using indicator variables and could not be transformed sufficiently reliably into logged values.

Finally, we estimated the association of percent change in total energy intake, body weight, and HOMA-IR on a percent change in price using pooled ordinary least square log-log regression models, clustered on the individual. For each model, the logged continuous food and beverage prices were regressed on the three logged outcomes variables, controlling for sociodemographic (race, gender, age, income, education, and family structure) and lifestyle factors (including total physical activity and smoking status) as well as logged values for selected complementary and replacement foods, logged COL, and an indicator variable for time (Year 0, Year 7), and imputed price data (yes/no). The weight models also controlled for subjects' height.

Exclusions

In all models, participants' observations were excluded if data were incomplete (n=64 observations) or the participant was pregnant (n=69 observations). This resulted in a final sample size for all MEM estimates of n=12,123 observations. Sample sizes varied for the linear regression step of the modeling process, depending upon the proportion of the sample that consumed the food (n=7,990 (soda); n=3,861 (whole milk); n=11,085 (orange juice); n=6,669 (hamburgers); and n=10,123 (pizza) observations). In the HOMA-IR model, participants were further excluded if they were taking anti-diabetic medication (n=182 observations), resulting in a final sample sizes for the longitudinal repeated measures regression models of n=12,007 (kcal), n=11,972 (weight), and n=10,218 (HOMA-IR score) observations.

C. Results

The inflation-adjusted real price of soda (price paid for a 2 L bottle) and pizza (price paid for a 13-inch, regular crust cheese pizza) steadily declined between 1985 and 2006, with the largest percent decrease observed for soda, falling from $2.71 to $1.42 (a 48% decrease, Table 1). The price of orange juice increased over the 20-year period, while away-from-home hamburger and whole milk prices were relatively stable. It is important to note, however, that these prices ignore the total cost as they do not incorporate the time cost involved in preparing food (Mincer 1963). Calories per person and per consumer from soda, adjusted for age and gender, increased steadily over the 20-year period, despite slight declines in the proportion of the population consuming soda (Table 1). On the other hand, there was a considerable decline in the proportion of the population consuming whole milk (-20.5%

between year 0 and 20) energy per person (-68 kcals between year 0 and 20) and energy per

consumer (-70 kcals between year 0 and 20).

Own price elasticities, price effects of specific food on consumption of that food,

were in the expected direction (for soda, orange juice and away-from-home pizza), although

these estimates were not always stronger than cross-price elasticities in a given model (Table

2). For example, an 18% increase in the price of soda resulted in a 12.81% (SE: 3.30,

$p<0.001$) decrease in consumption of daily energy from soda, a 7.39% (SE: 5.43, $p=0.173$)

increase in daily energy of whole milk and a 17.91% (SE: 7.11, $p=0.012$) increase in

consumption of daily energy from pizza. Save pizza, own price elasticities were < 1 (in

absolute terms) suggesting that US adults were relatively price inelastic (results not shown,

but they can be calculated: divide the results in Table 2 by 18).

Cross-price elasticities, price effects of a specific food on consumption of other foods,

can be useful in inferring complementary and replacement foods and beverages. For the most

part, cross-price elasticities were smaller than own price elasticity estimates. For example, an

18% increase in the price of pizza was associated with a 5.59% (SE: 2.57, $p=0.012$) increase

in the consumption of daily energy from soda (Table 2) compared to a 20.70% (SE: 5.51,

$p<0.001$) decrease in daily energy from pizza.

Annual household income was differentially associated with energy intake from

selected foods and beverages (Table 2) For example, low and middle income persons

consumed roughly 8.43% (SE: 1.01, $p<0.001$) and 5.23% (SE: 0.90, $p<0.001$) more more

kcals from whole milk, respectively, compared to high income persons. Similar patterns were

observed for soda while the opposite was true for away-from-home pizza: lower income consumers obtained fewer kcals per day from pizza compared to higher income persons (Table 2).

Using the mean total daily energy (kcals), body weight, and HOMA-IR values, we applied the energy, weight and HOMA-IR estimated elasticities to determine the association of these independent variables with increasing food and beverage prices. An 18% increase in the price of a 2 L bottle of soda was associated with an average 56.5 (SE: 12.2, $p< 0.001$) fewer total kcals (Figure 1), 0.8 (SE: 0.3, $p=0.015$) pound lower weight (Figure 2), and a 0.11 (SE: 0.02, $p<0.001$) lower HOMA-IR score (Figure 3), holding all other factors constant. Pizza was the only other food that had consistent (the three dependent variables were in the same direction) associations with total energy (-26.4 (SE: 35.5, $p=0.457$) kcals), body weight (-3.25 (SE: 1.02, $p=0.015$) lbs), and HOMA-IR score (-0.14 (SE: 0.06, $p=0.015$)).

Due to their strong cross-price elasticities, we also estimated the additive association of changing the price of soda, pizza or soda and pizza on total energy intake, body weight and HOMA-IR. A 10% increase in the price of both soda and pizza was associated with an additively greater percent change in total energy intake, body weight, and HOMA-IR scores compared to increasing the price of just one of these foods. For example, increasing the price of soda or pizza alone resulted in a 1.17% (SE: 0.24, $p<0.001$) and 0.52% (SE: 0.70, $p=0.457$) decrease in total energy while a 10% increase in the price of both soda and pizza resulted in a 2.27% (SE: 0.63, $p<0.001$) decrease in total energy. Similar patterns were observed for body weight and HOMA-IR scores (Figure 4).

D. Discussion

Price manipulations on unhealthy foods and beverages have been proposed as a potential mechanism for improving the diet and health outcomes of Americans (Cash et al. 2005; Chouinard et al. 2007; Popkin 2008). The state of New York has proposed an 18% tax on sugary sodas and soft drinks in an effort to reduce obesity and raise as much as $400 million per year for health programs (Chan 2008), and the city of San Francisco is considering similar legislation (McKinley 2007). While some argue that there is little evidence such a tax would improve health or positively impact obesity rates (Finkelstein et al. 2004), at least one cross-sectional study reported that a tax on caloric soft drinks drinks was inversely associated with weight, especially when the prices of complementary foods are also altered (Schroeter et al. 2008).

Our results, which are based on observed associations between food prices, consumption behavior, and health outcomes over a 20-year period, provide stronger evidence to support this conclusion: an increase in the prices of soda and pizza was associated with a decrease in consumption, declines in overall energy intake, reduced weight gain, and lower HOMA-IR scores. Using the elasticity estimates obtained in this study and mean daily energy, weight and HOMA-IR values in our sample, we estimate that the 18% tax proposed by the state of New York would result in a 56 kcal decline in daily total energy intake ((18 [proposed tax]*(-0.1116978 [estimated elasticity])*2811.9 kcal [mean daily kcals in our sample]), 0.8 pound lower annual weight gain ((18* (-0.0262884))*170.8 lbs), and 0.11 ((18* (-0.1891469)) *3.23 HOMA-IR) lower HOMA insulin scores among young to middle aged

adults. At the population level, declines of 56 kcal per day would be associated with a reduction of roughly 5 pounds per person per year, and significant reductions in the risks of most obesity-related chronic diseases (Wing et al. 1987; Wood et al. 1988; Goldstein 1992). It is important to note that price elasticities are usually higher for children and teenagers and the elderly, so the overall impact of the New York State tax on all its citizens might be greater than noted here (Grossman and Chaloupka 1997; Chaloupka et al. 2002; Liang et al. 2003; Warner 2005).

Furthermore, we found that real (inflation-adjusted) prices of soda and away-from-home foods, commonly associated with increased caloric consumption and adverse health outcomes (Schulze et al. 2004; Dhingra et al. 2007; Duffey et al. 2007; Vartanian et al. 2007; Rosenheck 2008), have decreased over time. Implementing policies aimed at slowing, or reversing, the decline in price for these foods could have a potentially beneficial effect on the health of the US adult population.

Our results are in the same direction as those reported elsewhere. In France and Italy demand elasticity was negative and relatively small for fluid milk, but more price sensitive to changes in income (Bouamra-Mechemache et al. 2008). Similar in direction but of greater magnitude, Barquera et al report that 10% price increases were associated with a decline of roughly 7 and 23 kcals per day from whole milk and soda respectively in a sample of Mexican adolescents and adults (Barquera et al. 2008). The considerable difference in magnitude of effects between the US and Mexican sample may indicate that US adults are less price sensitive, however a direct comparison is not possible due to differences in dietary

methodology (direct weighing and recipe collection versus food-frequency questionnaire) and study-design (cross-sectional versus longitudinal).

The observed own-price and cross-price elasticities we report in the current study provide further support for the observed effects on body weight and total energy. Own-price elasticities were strongest for soda and away-from-home pizza, with price inversely associated with consumption and although cross-price elasticities were sometimes in the opposite direction they had a smaller magnitude of effect. For example, a 10% increase in the price of soda was associated with a -7.1% decrease in calories kcals from soda, but only a 3.1% increase in calories kcals from pizza. Since a full range of potential complementary and replacement foods are not available, we are careful not to draw conclusions about the nature of the relationship between such disparate foods.

While there are many strengths as a result of using the CARDIA data, our analysis is limited by its focus on a small number of food and beverage groups. Additional and important substitution and complementary foods and beverages may exist and should be examined in future studies. The relationship between price and consumption of "healthy" food items (i.e. raw fruits and vegetables) should also be examined; our price data did not allow for evaluation of these relationships. Furthermore, we are not able to capture the full range of substitutability for the foods and beverages examined (i.e. using low-fat or skim milk if the price of whole milk increases, or choosing another fast food sandwich if hamburger prices rise), and thus we might have failed to take into account important explanations for our outcomes. Ideally, a full set of prices and food groups would have been

utilized, and the association between price and overall health examined using the demand approach frequently employed by economists, the Almost Ideal Demand System (Wu et al. 1995; Huang and Bouis 1996; Huang 1997).

Although we show significant differences by income, income did not modify the relationship between price and consumption in this sample. Deeper exploration of the interactions between food price and income may be crucial in other samples. Finally, this study has limited generalizability to non-US and younger populations. However, adolescents have been observed to be much more responsive to price changes in cigarettes than adults (Grossman and Chaloupka 1997; Chaloupka et al. 2002; Liang et al. 2003). We expect the relationship for price changes in foods and beverages to be similar.

Despite these limitations, ours is the first dietary behavior study in the US to examine both the *direct* effects of a price change on intake of a particular food (own-price elasticity) and the *indirect* effects on substitutes and complementary foods (cross-price elasticities). Furthermore by doing this over a long-term time period, we control for individual heterogeneity and are able to draw conclusions about how an individual's dietary behaviors would respond to changes in food price over a 20-year period. Finally, our findings highlight the substantial disparities between the fields of smoking and dietary behavior research. While there are extensive data sets on tobacco price and smoking behavior, there is a palpable scarcity of comparable data sets related to food price and consumption in the United States.

In conclusion, our findings suggest that national, state, or local policies which would alter the price of less healthy foods and beverages may be one possible mechanism for steering US adults toward a more healthful diet. While such policies will not solve the obesity epidemic in its entirety, they could prove an important strategy to address overconsumption, help reduce caloric intake, and potentially aid in weight loss and reduced rates of diabetes among US adults.

Table 1. Average price and energy consumption[*] from food and beverage groups at each exam year.

	Year 0	Year 7	Year 20	n	Pooled
Price ($)					
Soda	2.71 (0.31)	1.67 (0.17)	1.42 (0.24)	12,123	2.05 (0.63)
Whole Milk	2.00 (0.18)	2.04 (0.12)	2.24 (0.25)	12,123	2.08 (0.21)
Orange Juice	1.29 (0.42)	2.01 (0.33)	3.19 (0.76)	12,123	2.01 (0.92)
Hamburger	2.50 (0.18)	2.65 (0.26)	2.67 (0.22)	12,123	2.60 (0.23)
Pizza	13.48 (0.79)	12.01 (1.23)	10.80 (0.90)	12,123	12.32 (1.47)
Daily kilocalories Per Person [†]					
Soda	100 (2)	122 (7)	137 (20)	12,123	105 (2)
Whole Milk	100 (3)	54(4)	32 (8)	12,123	90 (2)
Orange Juice	115 (2)	114(9)	69 (11)	12,123	116 (2)
Hamburger	59 (2)	71(4)	133 (12)	12,123	62 (1)
Pizza	95 (2)	113(5)	74 (7)	12,123	100 (1)
Percent Consuming					
Soda	76.9 (3.4)	75.0 (8.0)	69.1 (20.7)	12,123	76.5 (0.3)
Whole Milk	46.5 (2.8)	33.0 (7.9)	26.0 (27.7)	12,123	43.4 (0.2)
Orange Juice	95.4 (6.8)	93.4 (14.4)	79.7 (26.6)	12,123	95.2 (0.5)
Hamburger	52.2 (2.8)	64.5 (7.4)	86.8 (21.4)	12,123	55.5 (0.2)
Pizza	84.5 (3.9)	88.0 (10.4)	83.1 (6.4)	12,123	85.4 (0.3)
Daily kilocalories Per Consumer[‡]					
Soda	131(3)	163(9)	219(38)	7,992	137 (23)
Whole Milk	204(6)	164(13)	134(45)	3,862	203 (5)
Orange Juice	120(2)	121(10)	85(12)	11,087	121 (2)
Hamburger	110(3)	110(6)	106(10)	6,670	109 (2)
Pizza	112(2)	129(5)	81(8)	10,125	117 (2)

*Values are mean (SD). Energy intake is rounded to nearest whole kilocalorie and are age and gender adjusted. Price data are real prices, in 2006 dollars, for a 2L bottle of soda (Soda), a one-half gallon of whole milk (Whole milk), a 6oz can frozen orange juice (Orange Juice), a ¼ lb hamburger purchased at a fast food restaurant (Hamburger), and a 13-inch cheese pizza, regular crust, purchased away-from-home (Pizza).

[†] "Per person" estimates include non-consumers; estimates apply to the entire sample, regardless of whether an individual consumed the food or beverage.

[‡] "Per consumer" estimates are restricted to consumers and estimates *only* apply to those who consumed the food or beverage.

Table 2. Relationship between 20-year price and consumption of foods and beverages[*] among adults, n= 12,123 observations.

	% change in energy from:					Income[‡]	
	Soda	Whole Milk	Orange Juice	Burger	Pizza	Low	Middle
18% increase in the price of:							
Soda[§]	-12.81 (3.30)[†]	7.39 (5.43)	-0.41 (1.79)	-7.57 (4.70)	17.91 (7.11)[†]	4.04 (1.11)[†]	3.67 (0.97)[†]
Whole Milk[‖]	-0.68 (3.32)	4.28 (5.83)	-3.67 (1.85)[†]	5.36 (4.24)	12.37 (6.70)	8.43 (1.01)[†]	5.23 (0.90)[†]
Orange Juice[#]	-3.53 (2.65)	-9.18 (5.00)	2.39 (1.63)	1.81 (3.75)	-0.33 (6.06)	-0.55 (0.83)	-0.15 (0.74)
Hamburger[**]	5.31 (3.14)	-0.70 (5.17)	-1.72 (1.75)	3.65 (4.49)	-10.93 (6.70)	-1.31 (1.07)	1.51 (0.93)
Pizza[††]	5.59 (2.57)[†]	-3.08 (4.42)	-3.03 (1.52)[†]	2.64 (3.55)	-20.70 (5.51)[†]	-4.48 (0.93)[†]	-1.45 (0.78)

[*] Values are elasticity (SE) derived from log-log models of daily calories from food or beverage on price of food or beverage. All models control for logged values for the price of soda, whole milk, orange juice, hamburgers and pizza as well as CARDIA study center, age (continuous), race, gender, education (completed elementary school, some high school, completed high school, some college, and completed college [referent]), family structure (single, married [referent], single with children, and married with children) annual household income (low (<$25,000), middle ($25,000- <$50,000), high (>$50,000) [referent]), logged cost of living index, imputed price (indicator, yes/no), and time (year 0, year 7, and year 20 [referent]). SE estimates calculated using 1000 bootstrapped replications. n= 12,123 observations.

[†] Significantly different from zero, p<0.05.

[‡] Relative to high income >$50K

[§] Soda model also controls for the logged price of wine, beer, and fried chicken (elasticities not shown).

[‖] Whole milk model also controls for the logged price of coffee (elasticities not shown).

[#] Orange juice model also controls for the logged price of bananas and bread (elasticities not shown).

[**] Hamburger model also controls for the logged price of fried chicken, parmesan cheese and steak (elasticities not shown).

[††] Pizza model also controls for the logged price of fried chicken (elasticities not shown).

Figure 1. Effects of an 18% increase in the price of selected foods and beverages[*] on 20-year percent change in total energy.

[*] Each food/beverage and outcome variable were modeled independently (n=15 models) as longitudinal linear regression models of logged outcome (total calories (kcal, n (Obs.)= 12,007), weight (lbs, n (Obs.)= 11,972), and HOMA-IR (n (Obs.)= 10,218)) on the logged price of soda, whole milk, orange juice, burgers, and pizza. All models controlled for age (continuous), race, gender, income (low (<$25,000), middle ($25,000-<$50,000), high (≥$50,000) [referent], missing income), education (< high school (HS), completed HS [referent], 3 years college, ≥ 4 years college), family structure (single, married [referent], single with children, married with children), logged cost of living, imputed price (indicator variable, yes/no), and CARDIA study center. Models with weight as the dependent variable also controlled for participants' height. Models adjust for clustering at the individual level. For all outcomes, individual food and beverage models further control for the price of the following compliment and replacement foods: **Soda models**: wine; **Whole milk models**: coffee, corn flakes, bread, and bananas; **Orange Juice models**: bread and bananas; **Hamburger (burger) models**: fried chicken, steak, and parmesan cheese; **Pizza models**: fried chicken.
[†] Estimate is significant at α<0.05 level.

Figure 2. Effects of an 18% increase in the price of selected foods and beverages[*] on 20-year percent change in body weight.

[*] Each food/beverage and outcome variable were modeled independently (n=15 models) as longitudinal linear regression models of logged outcome (total calories (kcal, n (Obs.)= 12,007), weight (lbs, n (Obs.)= 11,972), and HOMA-IR (n (Obs.)= 10,218)) on the logged price of soda, whole milk, orange juice, burgers, and pizza. All models controlled for age (continuous), race, gender, income (low (<$25,000), middle ($25,000-<$50,000), high (≥$50,000) [referent], missing income), education (< high school (HS), completed HS [referent], 3 years college, ≥ 4 years college), family structure (single, married [referent], single with children, married with children), logged cost of living, imputed price (indicator variable, yes/no), and CARDIA study center. Models with weight as the dependent variable also controlled for participants' height. Models adjust for clustering at the individual level. For all outcomes, individual food and beverage models further control for the price of the following compliment and replacement foods: **Soda models**: wine; **Whole milk models**: coffee, corn flakes, bread, and bananas; **Orange Juice models**: bread and bananas; **Hamburger (burger) models**: fried chicken, steak, and parmesan cheese; **Pizza models**: fried chicken.
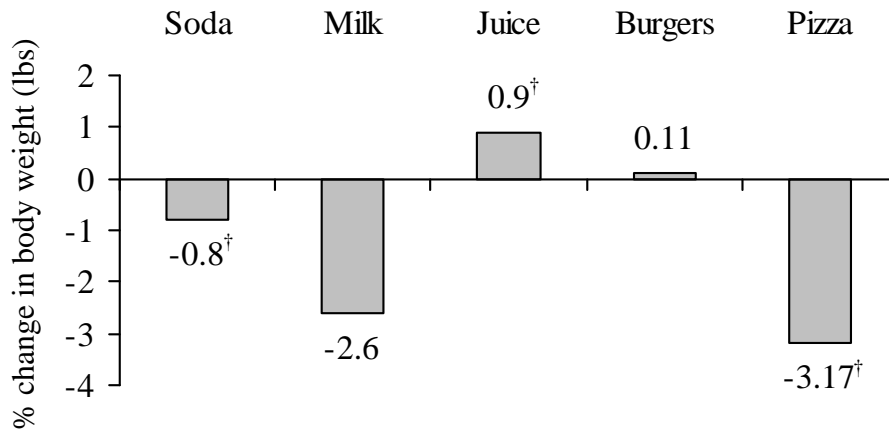[†] Estimate is significant at α<0.05 level.

Figure 3. Effects of an 18% increase in the price of selected foods and beverages[*] on 20-year percent change in HOMA-IR.

[*] Each food/beverage and outcome variable were modeled independently (n=15 models) as longitudinal linear regression models of logged outcome (total calories (kcal, n (Obs.)= 12,007), weight (lbs, n (Obs.)= 11,972), and HOMA-IR (n (Obs.)= 10,218)) on the logged price of soda, whole milk, orange juice, burgers, and pizza. All models controlled for age (continuous), race, gender, income (low (<$25,000), middle ($25,000-<$50,000), high (≥$50,000) [referent], missing income), education (< high school (HS), completed HS [referent], 3 years college, ≥ 4 years college), family structure (single, married [referent], single with children, married with children), logged cost of living, imputed price (indicator variable, yes/no), and CARDIA study center. Models with weight as the dependent variable also controlled for participants' height. Models adjust for clustering at the individual level. For all outcomes, individual food and beverage models further control for the price of the following compliment and replacement foods: **Soda models**: wine; **Whole milk models**: coffee, corn flakes, bread, and bananas; **Orange Juice models**: bread and bananas; **Hamburger (burger) models**: fried chicken, steak, and parmesan cheese; **Pizza models**: fried chicken.
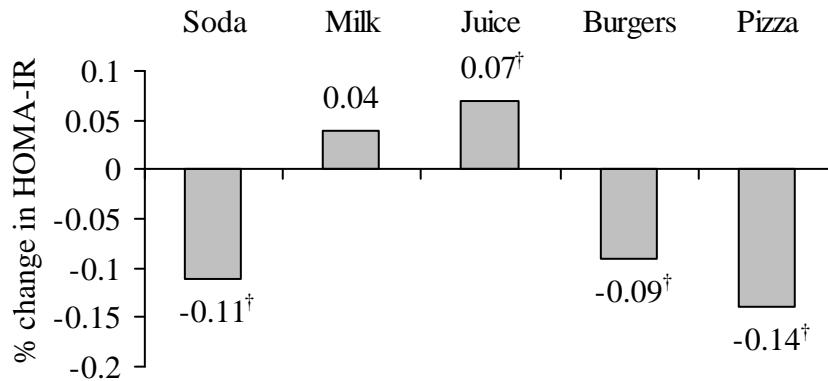[†] Estimate is significant at α<0.05 level.

Figure 4. Effects of a 10% increase in the price of soda, pizza or soda and pizza on percent change in total energy, body weight, and HOMA-IR score.

V. Differential metabolic associations between restaurant and fast food consumption: The CARDIA Study

A. Introduction

Away-from-home food (available in fast food places and restaurants) contributes significantly to daily caloric intake (Paeratakul et al. 2003) and accounts for roughly one-third of energy intake among certain subpopulations, particularly young adult males (Nielsen et al. 2002; Bowman et al. 2004). Fast food consumption has been associated with adverse health outcomes including increased risk of excess weight, body fatness, poor dietary quality, and insulin resistance/diabetes (McCrory et al. 1999; Paeratakul et al. 2003; Bowman et al. 2004; Bowman and Vinyard 2004; Pereira et al. 2005; Lindstrom et al. 2006; Duffey et al. 2007), all of which are hypothesized to result from the larger portion sizes (Young and Nestle 2002; Diliberti et al. 2004), higher energy density (Prentice and Jebb 2003; Schroder et al. 2007), or higher fat content of fast food (Stender et al. 2007).

Mechanisms for the direct contribution of fast food intake to the development of diabetes and other obesity-related co-morbidities, including dyslipidemia, have also been proposed and include higher levels of *trans* and saturated fatty-acids, low unsaturated:saturated fat ratio, greater portion sizes (Nielsen and Popkin 2003), and lower fiber content of fast food compared to foods obtained from other sources (Parillo and Riccardi 2004).

Cross-sectional (French et al. 2000; Satia et al. 2004) studies have demonstrated an association between away-from-home food consumption with weight and glucose outcomes, but these studies have limited ability to address causality due to concurrent assessment of exposure and outcome. Prospective observational studies (Pereira et al. 2005; Duffey et al. 2007) have also demonstrated an association between away-from-home food consumption with weight and glucose, but only one differentiated between restaurant and fast food intake (Duffey et al. 2007).

In cross-sectional and longitudinal observational studies it is possible that frequent away-from-home food consumption serves as a marker for unmeasured adverse health behaviors (i.e. sedentary lifestyles or sweet preferences) which underlie increased disease risk. Longitudinal modeling strategies, which control for unobserved and/or unmeasured individual level factors, are needed to address this point. Finally, while there exists extensive research on the association of fast foods with weight and insulin resistance, the relationship between away-from-home food consumption and a broad set of metabolic outcomes has not been examined, and there is a scarcity of studies examining the differential affects of fast food versus restaurant food intake. At least one study that has attempted to differentiate between these sources are limited by a short time duration (Duffey et al. 2007).

To address these limitations, the purpose of the present study was to examine the association between 1) average baseline away-from-home food (restaurant and fast food) consumption on 13-year health outcomes and 2) away-from-home food consumption with

13-year changes in health outcomes. Based on previous research in this population (Pereira et al. 2005; Duffey et al. 2007), we hypothesized that fast food and restaurant consumption would be differentially associated with weight, Homeostatic Model Assessment (HOMA) insulin resistance score, total cholesterol, triglycerides, low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) levels.

B. Methods

1. Study Population

Data were taken from The Coronary Artery Risk Development in Young Adults (CARDIA) study, a prospective study of the determinants and evolution of cardiovascular risk. Recruitment procedures were designed to create balanced representation of age, gender, ethnicity, and education groups within each of the four study sites. Five thousand one-hundred fifteen young adults (aged 18-30) completed the baseline survey (1985-86). Follow-up examinations were conducted at 2, 5, 7, 10, 15, and 20 years post baseline with retention rates of 91%, 86%, 81%, 79%, 74%, and 72% respectively. Data from exam years 7, 10, and 20 were used for this study. Detailed descriptions of the sampling plan and cohort characteristics are described elsewhere (Hughes et al. 1987; Friedman et al. 1988). The analytical sample included surviving cohort members who had complete outcome and covariate data at each time point. Exclusion criteria included pregnancy (n=92, all models), taking cholesterol-lowering medication (n=326, cholesterol models), or being diabetic, including taking anti-diabetic medication (n=303, HOMA-IR model). Sample sizes differed for each modeling framework and outcome variable (described below).

2 Away-From-Home Eating

Our main exposure, frequency of restaurant and fast food consumption, was ascertained at each exam year. Participants were asked "How many times in a week or month do you eat breakfast, lunch or dinner in a place such as McDonald's, Burger King, Wendy's, Arby's, Pizza Hut, or Kentucky Fried Chicken?" and subsequently "How many times in a week or month do you eat breakfast, lunch, or dinner at a restaurant or cafeteria?" Questions were open ended, but calculated to reflect a per-week consumption frequency.

2. Anthropometrics, Insulin Resistance & Blood Lipids

Measured height (nearest 0.5 centimeter (cm)) and weight (nearest 0.1 kilograms (kg)) were collected by trained technicians. Waist circumference (measured in centimeters (cm)) was measured midway between the iliac crest and the lowest lateral portion of the rib cage using the average of two measurements.

Fasting insulin, glucose and blood lipids were obtained by venous blood draw Glucose was measured using hexokinase coupled to glucose-6-phosphate dehydrogenase. The homeostasis model of insulin resistance (HOMA) was calculated as [glucose (mmol per liter) X insulin (µU per liter)]/22.5](Matthews et al. 1985).

Plasma total cholesterol and triglycerides were measured using enzymatic assay(Pesce and Bodourian 1976) at each follow-up visit. HDL-C was assayed after dextran sulfate-magnesium precipitation(Warnick et al. 1982), and LDL-C was estimated from the Friedewald equation (Friedewald 1972). LDL-C levels were not calculated for persons who

had measured triglyceride values >400 mg per deciliter (n=68). To convert cholesterol values to millimoles per liter (mmol/L) multiply by 0.0259 for total cholesterol, LDL and HDL-C, and 0.113 for triglycerides.

4. Covariates

Using standardized questionnaires, self-reported information on sociodemographic characteristics and selected health behaviors were collected including age, education (highest level achieved), smoking status, family structure (married, single, married with children, single with children), and sedentary behavior (hours of TV watched per day). Race (black vs. white) and gender were verified at each follow-up exam. Physical activity (PA), presented as Exercise Units (EU) per week, was assessed using the CARDIA physical activity questionnaire (Jacobs et al. 1989). For reference, 300 EU roughly approximates the American College of Sports Medicine recommendations for the amount of exercise needed to support weight loss (5 sessions of 300 kilocalories [1260 kilojoules] of weekly energy expenditure) (American College of Sports Medicine 1993). Due to non-linearity with the outcome, PA was dichotomized as high (≥ 474 EU per week) versus low (< 474 EU per week).

5. Statistical Analysis

All statistical analyses were conducted in Stata (version 10.0, College Station, TX). Using ordinary least-squares regression models we first examined the association between fast food and restaurant consumption (average of year 7 and 10 times per week, divided into quartiles: lowest quartile [referent]) with year 20 outcomes (weight, HOMA-IR, waist circumference, total cholesterol, triglycerides, LDL-C, and HDL-C) controlling for

sociodemographic (age, race, education, family structure, and CARDIA exam center) and

behavioral (smoking status, physical activity, hours of television viewing, total calories, and

change in fast food and restaurant consumption between year 10 and 20) covariates. Year 20

outcome values were obtained from each estimated beta coefficient using the ADJUST

command in Stata.

For each outcome, we used persons with complete data. Of those with complete

exposure and outcome data (n=2,439 (weight); n=2,238 (HOMA-IR); n=2,437 (waist

circumference); n=2,193 (total cholesterol, triglycerides, and HDL-C); n=2,170 (LDL-C)) we

excluded those missing covariate data (n= 1341 (weight); n=122 (HOMA-IR); n=133 (waist

circumference); n=117 (total cholesterol, triglycerides, and HDL-C); n=125 (LDL-C)) or

information on change in restaurant and/or change in fast food exposure between years 10

and 20 (n=672 (weight); n=606 (HOMA); n= 667 (waist circumference); n=603 (total

cholesterol, triglycerides, and HDL-C); n=596 (LDL-C)) resulting in final sample sizes of

n=1,633 (weight), n=1,510 (HOMA-IR), n=1,637 (waist circumference), n=1,473 (total

cholesterol, triglycerides, and HDL-C), and n=1,458 (LDL-C).

While estimates obtained from standard regression models, like those described

above, are useful in providing an estimate of the average effect of away-from-home food

consumption on subsequent health outcomes, these estimates can be influenced by

unobserved (i.e. an individual's motivation to be healthy) or unmeasured (i.e. knowledge of

the risk of being overweight) variables- particularly those that change over time. To address

this we use longitudinal, repeated measures conditional regression models (also known as

fixed-effect longitudinal models). Conditioned on the subject, these models estimate parameters for characteristics that are time-variant within the individual (e.g. weekly fast food consumption), while time invariant parameters (e.g. gender) are not estimated. Repeated measures conditional regression models are advantageous because they (1) adjust for potential confounding by all measured *and* unmeasured time invariant characteristics (e.g. genetic factors) that are not modifiers of the relationship of interest; (2) they partition error terms into within and between individual errors, and adjust for correlations between repeated measures taken on the same subject and (3) they are capable of handling unequally spaced longitudinal data.

For each model, time-varying fast food and restaurant consumption [continuous] were regressed on time-varying outcome variables [continuous], controlling for time-varying demographic (including age, education, and family structure) and lifestyle factors (including physical activity, sedentary behavior, and smoking status). Exclusion of persons with predicted residual values ≥ 4 standard deviation units (resulting in the exclusion of <1% of observations for all models) did not effect results so all observations were used. Using all available data across 13 years and 3 exam periods provided the following sample sizes [observations (subjects)]: Weight: 8,489 (3,987); HOMA-IR: 7,921 (3,873); waist: 8,472 (3,982); total cholesterol, triglycerides & HDL-C: 8,152 (3,926); LDL-C: 7,466 (3,450).

C. Results

As the population aged there was an expected increase in level of education, mean BMI and percent overweight and obese (Table 3). The difference in weekly consumption

between the lowest and highest quartile of fast food and restaurant consumption decreased over time, from 4·3 times per week at year 7 to just 2.0 times per week at year 20. Declines were similar for restaurant consumption, although the persons in the highest quartile of restaurant consumption consumed more restaurant meals per week than those in the highest quartile of fast food consumption (mean (SE): 3.4 (0.1) vs. 2.6 (0.1) times per week). PA and sedentary behavior changed very little (Table 3).

Compared to the lowest quartile of fast food consumption, persons in the higher quartiles has significantly higher year 20 weight and waist circumferences, HOMA-IR scores, triglyceride levels and significantly lower HDL-C levels (Table 4). For example, compared to the lowest quartile of fast food intake, persons in the highest quartile were an average 5.7 kg (95% Confidence Interval [95%CI]: 2.1, 9.2, p=0.002) heavier, had an average 5.3 cm (95% CI: 2.8, 7.9, p<0.001) larger waist, 22.7 mg/dL (95% CI:9.1, 36.3, p=0.001) higher triglyceride levels, and an average 5.5 mg/dL (95% CI:-8.3, -2.6, p<0.001) lower HDL-C level. Conversely, while the associations between greater weekly restaurant consumption tended to be in the opposite direction as that observed for increasing fast food intake, none of the estimates reached statistical significance (p>0.05).

Unlike the observed effects associated with baseline consumption and year 20 outcomes (Table 4), the addition of one additional weekly fast food or restaurant consumption eating occasion was positively associated with 13-year changes in weight and waist circumference (Table 5). In the fully adjusted models (Model 2) an increase of 3 times per week consuming fast food (restaurant) was associated with 0.45 kg (0.27 kg) weight gain.

Changes in waist circumference were small, but roughly equivalent between restaurant and fast food. Changes in fast food and restaurant consumption were unrelated to changes in HOMA-IR and cholesterol levels.

D. Discussion

Using prospective data spanning 13 years, we found that higher average baseline fast food, but not baseline restaurant, consumption was positively associated with year 20 health outcomes including weight and waist circumference, HOMA-IR score, and triglycerides and negatively associated with year 20 HDL-C levels. These associations are clinically relevant. For example, someone measuring 187 cm (1.87 meters) weighing 84.4 kg at year 20 would go from a year 20 BMI of 24.2 (year 20 BMI= [84.4/(1.87 m^2)]= 24.1) to a predicted year 20 BMI of 25.8 (predicted year 20 BMI = [(84.4+5.7 kg)/(1.87 m)^2] = 25.8) if they were in the highest compared to the lowest quartile of fast food intake.

Similarly, the average increase in triglycerides of 22.7 mg per deciliter in the highest (4th) compared to 9.4 mg per deciliter for persons in the second lowest (2nd) quartiles respectively results in a 4% increase in the proportion of the sample classified as having high year 20 triglyceride levels (≥150mg per deciliter) according to the National Cholesterol Education Program ATP III Guidelines (NHLBI 2002) (predicted triglycerides ≥150mg per deciliter: Quartile 4, 175 of 981 persons [17.8%]; Quartile 2, 111 of 829 persons [13.4%]). For persons with additional coronary heart disease risk factors this could be the difference between needing and not needing medication.

One additional weekly away-from-home eating event was also associated with greater 13-year anthropometric changes, although the absolute amount differed between restaurant and fast food. In longitudinal repeated measures conditional regression models, restaurant and fast food consumption were unrelated to changes in HOMA-IR score and cholesterol levels over the 13-year period.

For weight and insulin resistance outcomes, previous studies in this cohort report comparable findings. Pereira et al. found that persons who were frequent consumers of fast food at baseline and during 15 years of follow-up had greater weight gain than did infrequent consumers (persons who consumed fast food three or more versus one time per week gained an additional 2 kg) (Pereira et al. 2005), however effects of restaurant food consumption were not considered. To address this gap, our group compared three-year changes in fast food and restaurant consumption, and found that increased fast food only, or both restaurant *and* fast food consumption, were associated with three-year increases in BMI (0.20 kg/m^2 and 0.28 kg/m^2 respectively, $p<0.05$) while restaurant consumption alone was unrelated to BMI change (Duffey et al. 2007). The current finding that greater restaurant consumption is positively associated with 13-year changes in weight and waist circumference likely results from the use of more complex modeling strategies in which we model change in weight, not BMI, over a longer time span.

Despite control for many individual-level factors, significant relationships with away-from-home food consumption were observed. These findings may result from unmeasured area-level factors (e.g. neighborhood socioeconomic status, price of fast food) which could

influence whether restaurants versus fast food outlets were commonly patronized (Morland et al. 2002; Reidpath et al. 2002; Block et al. 2004), and we cannot discount the fact that such factors may be partially responsible for the differences in the associations between consumption frequency and change in weight (Liu et al. 2002; Gordon-Larsen et al. 2006). Individuals might also eat differently when visiting a fast food versus a sit-down style restaurant. Continued examination of area-level influences on individuals' dietary choices at away-from-home food places are needed to address these points.

Further limitations of this study include self-reported away-from-home eating and other lifestyle factors (which may bias our results toward (Heitmann and Lissner 2005) or away from the null (Heitmann and Frederiksen 2007)), potential residual confounding by unobserved, time-variant factors external to the individual, and an inability to differentiate between persons who consumed 1) healthier versus less healthy meals at various fast food locations or 2) persons who regularly consume from fast food restaurants where healthier food options are available from those places where such offerings are not present. Finally, many fast food restaurants have made considerable changes to their preparation methods (i.e. eliminating *trans*-fats) which are not captured by our data.

However, this study used comprehensive longitudinal, prospective data with high rates of retention across study years; outcomes were measured directly using standardized methods, which helps ensure more accurate assessment of anthropometric and biochemical measures; and, we are able to rule out structural confounding as a cause of our results

because there is considerable overlap in persons who are consumers of both fast food and restaurant food at each exam year (7 (82%), 10 (74%) and 20 (74%)).

To our knowledge, this is the first study to show that away-from-home food consumption is adversely associated with metabolic health outcomes, namely total cholesterol, triglyceride, and HDL-C levels, and to report important differences between restaurant and fast food intake. Future research should examine differences in the types of individual foods that are available and consumed at restaurants versus fast food places, and pilot studies should consider pricing or other promotions to educate individuals about the role of away-from-home eating in maintaining a healthy diet and preventing weight gain and its associated co-morbidities.

Table 3. Sociodemographic and behavioral characteristics[*] of CARDIA adults with complete data (n=3,643)

	All years
Black- % (SE)	51.6 (0.4)
Female- % (SE)	54.5 (0.4)

	Year 7 (1992-93)	Year 10 (1995-96)	Year 20 (2005-06)
Away-From-Home Eating[†]			
Fast Food- times/week	1.9 (2.5)	1.8 (2.0)[‡]	1.7 (2.4)[§]
Fast Food Intake, by Quartile			
Quartile 1	0.2 (0.01)	0.2 (0.01)	0.6 (0.1)
Quartile 2	0.8 (0.02)	0.9 (0.02)	1.4 (0.1)
Quartile 3	1.8 (0.04)	1.8 (0.04)	1.8 (0.1)
Quartile 4	4.5 (0.1)	3.9 (0.1)	2.6 (0.1)
Change from previous exam	--	-0.16 (2.4)	-0.13 (2.7)
Restaurant- times/week	2.3 (3.2)	2.1 (2.3)[‡]	2.3 (2.5)[‖]
Restaurant Intake, by Quartile			
Quartile 1	0.3 (0.3)	0.4 (0.01)	1.4 (0.1)
Quartile 2	1.1 (1.0)	1.0 (0.03)	2.0 (0.1)
Quartile 3	2.0 (1.9)	2.2 (0.1)	2.2 (0.1)
Quartile 4	5.7 (5.3)	4.3 (0.1)	3.4 (0.1)
Change from previous exam	--	-0.30 (3.4)	0.12 (2.8)[‖]
Demographics			
Age- y	32.0 (3.6)	35.0 (3.7)	45.2 (3.6)
Education- % (SE)[†]			
< High School	5.8 (0.4)	6.3 (0.4)	4.3 (0.3)[§,‖]
Completed High School	23.4 (0.7)	23.2 (0.7)	19.9 (0.7)[§,‖]
> High school	70.8 (0.7)	70.4 (0.7)	75.8 (0.7)[§,‖]
Smoking Status- % (SE)[†]			
Current Smoker	27.1 (0.7)	25.7 (0.7)	19.4 (0.7)[§,‖]
Former Smoker	15.7 (0.6)	16.4 (0.6)	19.4 (0.7)[§,‖]
Never Smoker	57.2 (0.8)	57.9 (0.8)	61.1 (0.8)[§,‖]
Family Status- % (SE)[†]			
Married, no children	20.0 (0.6)	17.3 (0.6)[‡]	18.8 (0.7)
Single, no children	31.3 (0.7)	28.0 (0.7)[‡]	23.8 (0.7)[§,‖]
Married, with children	37.0 (0.8)	42.7 (0.8)[‡]	43.7 (0.8)[§]
Single, with children	11.7 (0.5)	12.0 (0.5)	13.7 (0.6)[§,‖]
Anthropometrics			
BMI- kg/m^2	26.8 (6.1)	27.5 (6.5)[‡]	29.5 (7.2)[§,‖]
BMI < 25.0- % (SE)	44.6 (0.8)	39.6 (0.8)[‡]	27.8 (0.8)[§,‖]
BMI 25.0- 29.9- % (SE)	30.3 (0.7)	31.9 (0.7)	33.2 (0.8)[§]
BMI ≥30- % (SE)	23.2 (0.7)	26.5 (0.7)[‡]	38.1 (0.8)[§,‖]
Waist Circumference- cm	84.0 (14.1)	85.9 (14.6)[‡]	91.9 (15.6)[§,‖]

Table 3(continued). Sociodemographic and behavioral characteristics[*] of CARDIA adults with complete data (n=3,643).

	Year 7 (1992-93)	Year 10 (1995-96)	Year 20 (2005-06)
Blood Biomarkers			
Glucose - mg/dL	90.1 (19.4)	86.0 (8.6)[‡]	93.2 (10.0)[§,‖]
HOMA-IR	3.5 (5.6)	3.1 (2.3)[‡]	3.4 (2.4)
Total cholesterol- mg/dL	177.0 (34.3)	177.7 (34.2)	186.7 (34.6)[§,‖]
Triglycerides- mg/dL	86.4 (75.7)	91.5 (73.5)[‡]	107.3 (78.2)[§,‖]
LD-C- mg/dL	107.6 (31.6)	109.0 (31.8)[‡]	110.9 (32.0)[§,‖]
HDL-C- mg/dL	52.1 (14.2)	50.2 (14.0)[‡]	54.8 (16.8)[§,‖]
Physical Activity & Sedentary Behavior[†]			
Activity- exercise units/day	338.2 (273.9)	331.0 (275.0)	335.9 (274.2)
Television Viewing- hours/day	2.6 (1.8)	2.5 (2.0)	2.6 (2.3)

[*] Values are means (SD). To convert glucose values to mmol per liter multiply by 0.0555.To convert total cholesterol, LDL-C and HDL-C values to mmol per liter multiply by 0.0259, and to convert triglycerides values to mmol per liter multiply by 0.0113. BMI denotes body mass index, LDL-C low-density lipoprotein cholesterol, HDL-C high-density lipoprotein cholesterol, and HOMA-IR homeostasis model assessment of insulin resistance

[†] Data are self-reported and may reflect differences in reporting as well as consumption away-from-home eating) or participation (physical activity & sedentary behavior).

[‡] Significant difference using student's t-test [continuous] or chi-squared [categorical] tests Year 7 vs. year 10, p<0.01.

[§] Significant difference using student's t-test [continuous] or chi-squared [categorical] tests Year 7 vs. year 20, p<0.01.

[‖] Significant difference using student's t-test [continuous] or chi-squared [categorical] tests between Year 10 vs. year 20, p<0.01.

Table 4. Year 20 outcomes[*] associated with quartile of baseline fast food and restaurant consumption.

Year 20 Outcomes	n	Quartile Fast Food Consumption				Quartile Restaurant Food Consumption			
		1	2	3	4	1	2	3	4
Times/week		0-<0.5	0.5-<1.2	1.2-<2.5	≥2.5	0-<0.7	0.7-<1.5	1.5- <3	≥ 3
Weight (kg)	1,633	83.1	86.3	86.7	88.9	87.0	85.7	87.7	86.7
		(1.4)	(1.0)	(1.0)[†]	(0.9)[†]	(1.1)	(1.1)	(1.0)	(1.0)
HOMA-IR score	1,510	3.0	3.3	3.6	3.9	3.7	3.3	3.5	3.5
		(0.18)	(0.12)	(0.13)[†]	(0.14)[†]	(0.14)	(0.14)	(0.12)	(0.13)
Waist Circumference (cm)	1,637	89.0	91.8	93.2	94.4	93.5	91.6	92.8	92.5
		(1.0)	(0.7)[†]	(0.7)[†]	(0.7)[†]	(0.8)	(0.8)	(0.7)	(0.7)
Total Cholesterol (mg/dL)	1,473	188.0	184.6	186.7	188.3	185.9	186.2	186.0	189.0
		(2.5)	(1.9)	(1.9)	(1.7)	(2.0)	(2.0)	(1.7)	(1.9)
Triglycerides (mg/dL)	1,473	94.8	104.2	113.5	117.5	111.8	108.1	107.3	111.7
		(5.4)	(3.9)	(3.9)[†]	(3.6)[†]	(4.3)	(4.2)	(3.7)	(4.0)
LDL-C (mg/dL)	1,458	111.4	111.8	111.3	113.4	111.9	111.3	111.5	113.8
		(2.3)	(1.7)	(1.7)	(1.6)	(1.8)	(1.8)	(1.6)	(1.7)
HDL-C (mg/dL)	1,473	57.5	52.6	53.3	52.0	52.8	53.7	53.4	53.2
		(1.1)	(0.8)[†]	(0.8)[†]	(0.7)[†]	(0.9)	(0.9)	(0.8)	(0.8)

[*] Values are predicted mean year 20 outcomes (SE) obtained using beta coefficients from ordinary least squares regression models of year 20 outcome (continuous) comparing quartile of weekly fast food and restaurant consumption (average Year 7 and 10, Quartile 1 [referent]), controlling for age (32-34y, 35-37y, ≥38y vs. <32y [referent]), race (black vs. white [referent]), gender, education (< HS, >HS vs. HS/GED [referent]), family structure (married, married with children, single, vs. single with children [referent]), CARDIA study center (Birmingham, Chicago, and Minneapolis vs. Oakland [referent]), physical activity (≥474 EU per week vs. <474 EU per week [referent]), television viewing (hours per day, continuous), Year 7 total calories (continuous), smoking status (current, former vs. never [referent]), and change in fast food and change in restaurant consumption (year 20 minus year 10). To convert total cholesterol, LDL-C and HDL-C into mmol per liter multiply by 0.0259. To convert triglycerides to mmol per liter multiply by 0.0113. HOMA-IR denotes homeostatic model assessment of insulin resistance, LDL-C low-density lipoprotein cholesterol, and HDL-C high-density lipoprotein cholesterol.
[†] β coefficient p-value < 0.05.

60

Table 5. Longitudinal associations between weekly fast food and restaurant consumption with 13-year change[*] in outcomes.

13-year change in outcomes	n	Obs.[†]	Fast Food β (SE) Model 1[‡]	Fast Food β (SE) Model 2[§]	Restaurant Food β (SE) Model 1[‡]	Restaurant Food β (SE) Model 2[§]
Weight- kg	3,987	8,489	0.15 (0.05)[‖]	0.15 (0.05)[‖]	0.09 (0.04)[¶]	0.09 (0.04)[¶]
HOMA-IR score	3,873	7,921	0.02 (0.01)	0.02 (0.01)	0.007 (0.01)	0.01 (0.01)
Waist Circumference- cm	3,982	8,472	0.13 (0.04)[‖]	0.12 (0.04)[¶]	0.07 (0.03)[¶]	0.08 (0.03)[¶]
Total Cholesterol- mg/dL	3,926	8,152	0.15 (0.15)	0.15 (0.15)	0.10 (0.12)	0.11 (0.12)
Triglycerides- mg/dL	3,926	8,152	0.24 (0.40)	0.21 (0.40)	0.18 (0.31)	0.23 (0.31)
LDL-C- mg/dL	3,450	7,466	0.16 (0.14)	0.16 (0.14)	-0.01 (0.11)	0.004 (0.11)
HDL-C- mg/dL	3,926	8,152	0.08 (0.06)	0.09 (0.06)	0.07 (0.05)	0.06 (0.05)

[*] Values are beta coefficients (SE). To convert total cholesterol, LDL-C and HDL-C to mmol per liter multiply by 0.0259. To convert triglycerides to mmol per liter multiply by 0.0113. HOMA-IR denotes homeostatic model assessment of insulin resistance, LDL-C low-density lipoprotein cholesterol, and HDL-C high-density lipoprotein cholesterol.

[†] Derived from number of observations (Obs) across three time periods (exam years 7, 10 and 20) per person (n). Values range from one to three, with an average of 2.1 observations per person.

[‡] Model 1 is a repeated measures, conditional longitudinal model of outcome (continuous) on weekly fast food and restaurant consumption (continuous), controlling for the time-variant factors age (continuous), education (<HS, >HS, vs. HS/GED [referent]), and family structure (married, married with children, single, vs. single with children [referent]).

[§] Model 2 is model 1 plus the time-variant lifestyle factors physical activity (EU per week, continuous), television viewing (hours per week, continuous), and smoking status (current, former vs. never [referent]).

[‖] Coefficient is significant using Wald Test, p<0.001.

[¶] Coefficient is significant using Wald Test, p<0.05.

VI. Synthesis

A. Overview of findings

      This research investigates the economic determinants of beverage and away-from-home food consumption and explores the consequences of these decisions on weight and metabolic outcomes. Using 20 years of diet and health data from the Coronary Artery Risk Development in Young Adults Study, linked by residential location to community food and beverage prices, our analyses make valuable contributions to the field by advancing our understanding of the influence of food price on dietary behavior and identifying the differential effects of restaurant and fast food consumption on health. These findings fill substantive gaps in the literature and have important implications for the creation of effective educational campaigns, obesity interventions or prevention efforts, and state and national nutrition policies. What follows is a brief summary of our findings, a synthesis of their implications, and discussion of directions for future research.

1. Price influences individuals' consumption behaviors and health outcomes

      Using prices and dietary intake directly measured at the level of the individual, we examined associations between the percent change in food and beverage price with (1) percent change in daily energy from the selected beverages and away-from-home foods and (2) percent change in total energy intake, body weight, and HOMA-IR scores. We report that as the price of a given food increased, daily energy intake from that food, total daily energy

intake, body weight, and HOMA-IR scores decreased. For example, an estimated 10% increase in the price of soda was associated with an estimated 7.1% decrease in daily energy from soda, 1.1% decrease in total energy, 0.3% decline in body weight gain, and 2.0% decline in HOMA-IR score over 20-years. Furthermore, we found that increasing the price of a combination of foods and beverages resulted in declines total energy intake, weight gain, and HOMA-IR scores that were greater than those observed for changes in a single food item. In conclusion, these results highlight the importance of price as a determinant of consumption behavior and provide support to the call for national, state, or local policies that would alter the price of less healthy foods and beverages as a potential mechanism for improving the diets of US adults.

This research fills several substantive gaps in the literature. First, prior research on the relationship between food price and consumption has relied on aggregate measures of consumption (extrapolated to the individual) or theoretical models of behavioral responses to price change. Our research, on the other hand, utilized measures of price and dietary intake, which were measured directly at the level of the individual. Thus, our results more closely approximate the experiences faced by individuals and provide some evidence for expected behavior change associated with changing food prices. Furthermore, our research significantly advances the literature on this topic by following individuals over a 20-year period. In doing so, we control for individual heterogeneity and are able to draw specific conclusions about the response of dietary behavior to changes in food price over time.

2. Restaurant and fast food consumption have differential associations with health outcomes

Using 13-years of prospective data from black and white young adults, our objective was to examine the relationship between changes in the weekly frequency of restaurant versus fast food consumption with changes in multiple health outcomes including weight, waist circumference, HOMA-IR, total cholesterol, triglycerides, LDL-C and HDL-C levels.

Compared to those in the lowest quartile of baseline fast food consumption, persons in the highest quartile had significantly higher year 20 weight, waist circumference, HOMA-IR scores, and lower HDL-C levels. These relationships were not observed for weekly restaurant consumption: individuals in the highest quartile had no difference in 20-year health outcomes compared to those in the lowest quartile. Furthermore, increased weekly frequency of both restaurant and fast food consumption over the 13-year period were associated with greater weight gain and changes in waist circumference, but the effect was larger for persons who increased their fast food intake.

Previous studies investigating away-from-home food consumption and health outcomes have often failed to differentiate between these two food sources. From a methodological standpoint, our results highlight the importance of examining the independent effects of consuming foods from restaurants versus fast food outlets, particularly when baseline intake is used to predict subsequent health outcomes. Failure to account for the differential associations between these two exposures may result in estimates which are biased toward the null. Furthermore, this study advances our understanding of the

64

consequences of away-from-home eating, by examining the relationship between fast food

and restaurant consumption with multiple metabolic health outcomes including total

cholesterol, triglycerides, LDL-C and HDL-C levels. To our knowledge it is the first study to

do so. Finally, this work emphasizes the importance of public health promotion efforts which

target regular consumers of fast food. Identification of healthier food options available at fast

food outlets, the provision of nutritional information or accessible educational materials to

help consumers make more informed choices, or the use of health messages targeting specific

away-from-home consumption behaviors are potentially efficacious methods for reducing the

long-term adverse consequences of frequent fast food consumption.

B. Limitations and Strengths

Perhaps the biggest challenge in dietary research lies in our ability to accurately

capture intake. Our assessment of dietary intake and the frequency of away-from-home food

consumption was data based on self-reported FFQ data. Self-report data are subject to

measurement error and recall bias, and can result in inaccurate assessment of diet

(particularly when the recall time-frame is large), or misclassification of usual dietary

practices. Although alternative means of capturing dietary intake are available, food

frequency questionnaires (such as the Diet History utilized in the CARDIA study) have

become the preferred method for measuring dietary intake in large-scale epidemiologic

studies (Willett 1998) and the CARDIA Diet History employed several strategies to

minimize recall error (Liu et al. 1994), including the use of trained technicians to administer

the questionnaire. Nevertheless, difficulty in recalling dietary intake and accurately

evaluating the frequency of away-from-home food consumption may lead to

misclassification. This non-differential misclassification would result in estimates that are biased toward the null. Categorization by quartile of intake, as we used for portions of this research, helps to reduce misclassification in our analyses.

Ideally, study of the relationship between price and intake would capture prices of the full range of foods and beverages available for consumption as this allows for evaluation of the *total* effects of price on health. Unfortunately, our results are constrained by the limited number of food and beverage prices for which we had overlapping dietary intake data. Overwhelmingly, missing prices were of healthier food and beverage options. For example, lettuce was the only fresh vegetable for which price data were available, and there was no matching "lettuce" food group. This further restricted our ability to fully evaluate the effect of substitutability between related products, for example the replacement of low-fat for whole-fat milk. Despite these limitations, selection of food and beverage prices was guided by careful consideration of hypothesized relationships between the variables of interest. In doing so, we were able to maximize utilization of the fixed number of diet and price variables available.

Another important limitation to our analyses is that they do not identify the particular foods and beverages consumed at restaurants and fast food places, and thus we cannot determine if there are differences in the dietary patterns of individuals who are frequent versus infrequent consumers of away-from-home foods, or between frequent consumers of food from restaurants versus fast food places. This inability to expressly examine dietary patterns may result in dilution of our estimated effects. For example, persons who regularly

consume salads from a fast food restaurant may have very different associations with health outcomes compared to persons who regularly consume hamburgers and French fries. If these effects are in opposing directions, failure to account for the differences would result in diluted effects. However, our research provides important insight to the differences that exist between restaurant and fast food consumption and highlights areas where future studies might offer additional understanding of the relationship between away-from-home eating and health.

Finally, in this research we cannot fully account for endogeneity, and thus our ability to infer causal relationships is limited. Endogeneity arises when the outcome and exposure variables are correlated with a third, often unmeasured or unobserved, variable or when variables within a system (within a model) are predicted by other variables within the system. This can be a particularly salient issue for longitudinal data, and analyses where exposure and outcome are multifactorial, particularly when the data are not analyzed using appropriate statistical techniques. For example, there may be unmeasured individual characteristics which influence an individuals' decision to consume fast food and that also impact weight status.

Although we utilized fixed-effect models in an attempt to address endogeneity, fixed effect models can only control for endogeneity arising from time *invariant* factors or individual characteristics. Unmeasured or poorly measured time *variant* characteristics, however, are not accounted for using fixed effect models. This may partially explain our failure to find an effect in longitudinal models of away-from-home food consumption on

weight and metabolic outcomes (aim 2), where one was observed using cross-sectional analyses: change in an individual's motivation to improve their health, an unmeasured time-variant characteristic, could be affecting both their weight status and their frequency of fast food consumption. We are less concerned about endogeneity in aim 1, as our exposure variable is fully exogenous (i.e. not predicted by any other variable contained within the model).

Despite these limitations, this body of research has many strengths. Although there has been increased interest in examining the effects of away-from-home eating on health, few studies have attempted to characterize, or independently examine, different types of away-from-home food sources. Our research on the differences between fast food and restaurant consumption has highlighted some striking differences between these two food options, and may partially explain some of the discrepant findings in the literature on this topic.

The longitudinal, prospective nature of our data was another strength. Using multiple waves of data, collected over decades, enabled us to test for time-dependent factors associated with fast food and beverage price, consumption, and long-term health outcomes. Furthermore, these data, in combination with our application of powerful methodological modeling strategies, allowed us to partially control for time-invariant unobserved and unmeasured characteristics and to increase the precision of our estimates. Finally, longitudinal studies are important for establishing temporality; thus our research makes a considerable contribution to the field which has largely used cross-sectional data to analyze these relationships.

Finally, although many studies have attempted to estimate the effect of food price on consumption, these studies overwhelmingly use household or aggregate (regional or national level) expenditure data to represent the food costs experienced by individuals. Further, most studies draw on global measures of availability, rather than consumption, or utilize aggregate measures of consumption and estimate to the individual-level. Examples of these types of data and research questions include using national estimates of sugar availability to evaluate individual-level sugar consumption, or using household spending on dairy products to estimate per person costs associated with milk consumption. The defining limitation of these studies is that they do not directly link food prices faced by an individual to that individual's dietary patterns or subsequent health outcomes.

This is a major strength of our research, and fills an important gap in the literature. We utilized directly measured health and diet data, which were linked both spatially and temporally to prices of a variety of foods and beverages as well as other consumer goods and services. This allows us to more accurately represent the experience of the individual, and because these data extend over a full 20-year period, to examine directly how changes in food price are associated with changes in individual-level purchasing behaviors and health outcomes. Related, the quality of the CARDIA diet and health data is a significant strength of this research. Health outcome data (i.e. weight, blood pressure) were collected by trained technicians using repeat measures; the standardized diet history questionnaire, designed specifically for the CARDIA sample, has been shown to produce valid and reliable estimates of dietary intake; and loss to follow-up was minimal.

C. Public Health Significance

In this uncertain economic time, when health-care costs are escalating, and the prevalence of preventable chronic conditions, such as obesity and the metabolic syndrome, continue to rise, the seemingly simple decision "What should I eat?" is becoming increasingly complex. The decision is influenced by myriad factors acting on multiple levels and has considerable ramifications for health. Our research, which critically examined the determinants and consequences of dietary intake, has important implications for advancing the public's health by informing effective intervention strategies and nutrition policies aimed at arresting the rates of obesity and obesity-related chronic disease development.

1. Price policies could effectively alter consumption behaviors

We found that price increases for selected beverages and away-from-home foods were associated with decreased energy intake from those foods, as well as global declines in total energy intake, body weight, and HOMA-IR scores over a 20-year period. Individuals seemed to be particularly sensitive to changes in the price of soda and away-from-home pizza, and the associated health effects were even greater when the price of both foods were altered when compared to the estimated effects of changing the price of soda or pizza alone.

Price is often cited as a motivating factor determining food choice (Finkelstein et al. 2004; Cardello and Garr (In Press) 2009). Aligned with these findings, our findings suggest that local, state, or national policies aimed at adjusting the price of less healthy food items may be one possible mechanism by which to impact consumption patterns and health.

Numerous states have passed (or are proposing to pass) laws regulating the price of foods

containing sugar and fat (Chouinard et al. 2007). Our findings suggest that fiscal

interventions, such as taxes, could result in reduced consumption, and may have long-term

health benefits related to decreased energy intake and weight change. This has clearly been

observed in the tobacco literature, where taxation has resulted in a reduction in smoking

rates, particularly among adolescents (Grossman and Chaloupka 1997; Chaloupka et al.

2002; Wakefield et al. 2008).

Our findings also highlight the need to consider pricing of multiple foods and

beverages, particularly foods and beverages that could serve as replacement items for the

taxed good. Given the wide array of food items available to consumers, it is shortsighted to

assume that narrowly defined taxes, applied to a single food or beverage item, will have

consequential effects on health, particularly health outcomes with multidimensional dietary

and behavioral determinants. For example, taxes levied on sugar-sweetened beverages might

result in little improvement in health if consumers simply switch to 100% fruit juice or a

high-fat beverage, especially if total energy intake is not affected. Taking into account

overall dietary patterns and the relationships between various foods and beverages, will

likely result in price policies which have greater influence on purchasing behavior,

particularly if those policies have clearly defined objectives and are not overly burdensome

to selected subgroups (i.e. lower income individuals) (Finkelstein et al. 2004).

2. Successful intervention strategies will need to consider food price

As evidence of a link between diet and disease has grown stronger, recent decades have witnessed an immense proliferation of interventions aimed at altering unhealthy dietary behaviors and promoting healthier ones. Increased consumption of fruits and vegetables, fiber, low-fat meats or dairy, reduction in sugar-sweetened beverages, red meat, saturated fat, total fat, and decreased snacking have been the goals of numerous nutrition interventions. Regardless of the dietary target, most interventions employ a similar set of techniques: provision of education materials or use of motivational strategies aimed at increasing knowledge and self-efficacy to consume (or not consume) the targeted food, utilization of schools or worksites as a means to increase (decrease) availability, and use of grocery store point-of-purchase labeling to increase (decrease) sales.

Some, but not all, of these interventions have resulted in successful behavior change, but these changes are not always sustained long-term. This may partly be due to the narrow-scope of the intervention methods. Price has been shown to play an important role in determining dietary behavior, and some studies have demonstrated that the combination of education and changes in price is a particularly powerful method for altering purchasing and consumption (Jeffery et al. 1994; French et al. 2001; French 2003). Price is a particularly salient issue for interventions whose goal is to increase intake of the more expensive, nutrient-rich foods, such as fruits and vegetables (Drewnowski et al. 2004; Drewnowski and Darmon 2005).

We have shown that individuals respond to changes in food price and that complex interactions between food prices, consumption behaviors, and health outcomes exist. Particularly at set incomes, individuals will likely make decisions which maximize energy intake while minimizing food costs (Drewnowski and Darmon 2005). If this is the case, then simply encouraging low-income households to consume more costly foods is an ineffective public health strategy, and food price needs to be considered if long-term dietary strategies are to be maintained or dietary recommendations adhered to.

3. Identification or provision of healthier food options at fast food outlets may benefit consumers' health

Away-from-home eating is often targeted as a modifiable risk factor for obesity prevention efforts and is cited by the World Cancer Research Fund-American Institute for Cancer Research as a probable cause of weight gain, overweight, and obesity "which should be consumed sparingly, if at all (World Cancer Research Fund / American Institute for Cancer Research 2007)." However, our findings suggest that this blanket statement may be slightly misleading: distinct from other research, our findings show that frequent consumption of fast food, but not consumption of sit-down style restaurant food, is adversely associated with multiple health outcomes. Over a 13-year period, higher baseline consumption of fast food resulted in higher weight, waist circumference, HOMA-IR scores, and lower HDL-C levels, but these associations were not observed for higher consumption from restaurants.

The decision to consume food outside the home is influenced by a variety of factors and although health is not always one of them, our findings suggest that empowering individuals' in their capacity to make the healthiest dietary choices possible, particularly when patronizing fast food places, may have beneficial effects on health. Labeling is one such mechanism by which consumer choices might be influenced. Requirements for labeling of *trans*-fats resulted in the adoption of healthier ingredients and preparation techniques used at many fast food chains (Center for Science in the Public Interest 2006; Horovitz 2006) and it is hoped that a recent initiative in the city of New York, which requires fast food outlets to post calorie information on their menu boards, will spur similar improvements in other aspects of fast food menu offerings.

Also important is engagement of the restaurant and food industry as active participants in improving the quality of their product. To some extent, fast food outlets have done this: eliminating trans-fats from their cooking oils and super-sized options from their menus. However, at least one study reported that profit margins are the primary determinants of why food retail outlets do (or do not) add (or continue to serve) a given food item (Glanz et al. 2007; Cardello and Garr (In Press) 2009), so without increased consumer demand there is little incentive for restaurants and fast food places to continue to offer healthier products. Furthermore, studies have indicated that most patrons are unaware of the high levels of calories, fat, and sodium found in many menu items (Burton et al. 2006), but those that were tended to have healthier diets (Variyam 2008). Without full disclosure by restaurants and fast food places, uninformed consumers cannot be expected to demand healthier options.

In summary, informational campaigns educating individuals about the long-term health consequences of their away-from-home eating habits, intervention strategies or nutrition policies that provide consumers with the tools necessary to make healthy and informed decisions at fast food places, and initiatives aimed at engaging the restaurant industry in the improvement of their products can help ensure future public health.

D. Future Directions

There are many natural extensions of this research that could help advance our understanding of the determinants of food and beverage consumption and identify possible means of preventing excess weight gain and weight-related co-morbidities.

1. Identify additional determinants of away-from-home eating

A crucial area for future research involves examination of additional factors which influence an individual's food purchasing decisions, particularly their decision to consume food away-from-home. Income is one such factor. Although commonly cited as a determinant of away-from-home eating, income functions as a coarse proxy for a more complex set of factors which may, or may not, have critical influences on decisions regarding consumption. For example, income may represent greater amounts of free time, a higher level of education regarding the importance of maintaining a healthy lifestyle, increased access to healthier foods, and/or greater motivation to engage in healthy dietary or activity patterns. Future analyses will benefit from a deconstruction of many of these broad-scale factors and a closer examination of their underlying component parts. Such results, in turn, will help identify more specific target areas for future interventions and nutrition policies.

By extension, future studies should also explore the role of the food environment as a potential determinant in shaping individual behaviors associated with disease development. With respect to dietary patterns and obesity, understanding the food environment as it relates to the availability of food stuffs is particularly salient as convenience and availability are important predictors of food habits (Glanz et al. 1998; Croll et al. 2001; Neumark-Sztainer et al. 2003; Inglis et al. 2005) and might directly influence individual dietary behaviors through targeted placement of food stores (Block et al. 2004; Austin et al. 2005).

Area level factors might also have important mediating effects between individual-level dietary determinants and diet or health outcomes. Numerous studies have demonstrated differential access to food places, including supermarkets, smaller grocery stores, restaurants and fast food places, by neighborhood deprivation, ethnic composition, and area-level wealth (Morland et al. 2002; Reidpath et al. 2002; Cummins et al. 2005; Moore and Diez Roux 2006; Pearce et al. 2007). Such factors are typically measured at the individual-level (i.e. using variables such as race or income), but observed associations between these factors and health may be mediated through area-level factors. Development of more effective intervention studies can be informed by examining the relationship between individual and area-level predictors of behavior and health, as well as deepening our understanding of the proximate influences those area-level factors have on behavior.

2. Determine the specific foods consumed away-from-home

In addition, future studies should refine research on the relationships between away-from-home eating and health by collecting detailed information on the types of foods consumed from restaurants versus fast food outlets. For example, building upon our research assessing consumption frequency, future research could also investigate how the specific dietary patterns of frequent restaurant versus fast food consumers differ from one another. In doing so, we might identify whether or not regular consumers of one food source or another have healthier overall dietary intake, or determine if subsets of consumption patterns exist (i.e. high intake of soup and salad among those who are frequent consumers of fast food). This type of research is imperative for better understanding of the role away-from-home eating plays in the development in obesity and obesity-related co-morbidities and will inform future public health messages regarding away-from-home eating and health.

3. Examine price influences of healthier food items

Building upon our research, which was limited by a narrow list of available food and beverage items and precluded the study of healthier food options such as fresh vegetables and fish, future prospective analyses should carefully consider the relationship between price and consumption of such healthier food items, as well as the complex exchanges between these foods and potential replacement goods. Many argue against taxes on high-sugar or high-fat foods because they are regressive, imposing a greater burden on the poor compared to the rich. Others believe that imposition of taxes on a select group of ["unhealthy"] foods and beverages establishes an unnecessary dichotomy of "good" versus "bad" foods: leading to a culture of fear where those bad foods are to be avoided wholesale. Subsidies, typically for

fresh fruits and vegetables, are frequently offered as alternatives to taxation policy because they do not put undo burden on lower income individuals and promote, rather than discourage, desired behaviors. However, more evidence is needed to show that subsidies would result in the desired change in purchasing or consumption behaviors. Equally important is the continued assessment of income as a predictor and mediator in these relationships, as lower income individuals are most often the intended beneficiaries. The long-term ineffectiveness of so many current nutrition intervention efforts, particularly among lower income individuals, suggests that targeting upstream factors associated with dietary intake may prove beneficial, and when taken in combination with our results, will inform future nutrition policies.

4. Monitor and evaluate recent policy initiatives

Finally, within recent months policies have been (or will be) passed which have the goals of (1) increasing consumer awareness by providing calorie information at fast food places or (2) altering consumption behavior by increasing prices of high fat, high sugar foods and beverages. With the passing of such policies, public health researchers have the distinct opportunity to examine the consequences in a real world setting, and to determine the degree to which such policies are able to meet their objectives. Our research suggests that both policies should successfully influence consumption decisions and may even lead to reductions in adverse health outcomes, particularly the prevention of weight gain. Continued monitoring of the dietary and health implications of these policies is an opportunity that should not be wasted and can inform future interventions and national nutrition initiatives.

E. Conclusion

A recent advertisement by a well known fast food restaurant features a young couple, engaged in routine activities, maximizing the value of the items they purchase. The husband, in particular, finds somewhat ridiculous ways to accomplish this goal: for example using an industrial-sized vice to squeeze out the last of the toothpaste. In the final scene we see him with a jack hammer tearing up the sidewalk in front of his home, the walkway and front steps lay in pieces behind him. As his wife approaches she says "I thought we were only going to redo the steps" to which he responds, "No honey. I rented this for the whole day. I'm going to get my money's worth." Holding up a take-out bag his wife responds, "I thought we might try this instead." Smiling, he puts down the jack hammer and they enjoy their hamburgers together.

This commercial tells a very particular story about food, one that highlights the importance of value and the means by which that value can be obtained- through the purchase of fast food. The story is not false, but by defining value in this way it ignores the consequences of consuming such a diet and discounts the future costs associated with that decision. Our research provides a different perspective about food, one that highlights the important consequences of our food purchasing and consumption decisions and attempts to understand the motivations behind those behaviors. These findings do not tell the whole story either, as the set of predictors and outcomes associated with dietary behavior is far more complex than we have examined in these analyses, and considerable work remains to fully elucidate these relationships.

The division between these two messages, between the two narratives put forth by the food industry and public health nutrition science, is the space in which our research becomes relevant. It underscores the importance of disseminating information to consumers regarding the consequences of their food decisions; it speaks to the power that scientific research has to influence local, state, and national nutrition policies; reminds us of the continued need to rigorously pursue answers to relevant scientific questions; and encourages translation between science and public interest. By engaging in conversations within this space we will begin to tell a more complete story about food and health.

<center>**REFERENCES**</center>

Alberti, K. G., P. Zimmet, J. Shaw and I. D. F. E. T. F. C. Group (2005). "The metabolic syndrome--a new worldwide definition." <u>Lancet</u> **366**(9491): 1059-62.

American College of Sports Medicine (1993). "The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Position stand of the American College of Sports Medicine." <u>Schweiz Z Sportmed</u> **41**: 127–137.

Austin, S. B., S. J. Melly, B. N. Sanchez, A. Patel, S. Buka and S. L. Gortmaker (2005). "Clustering of fast-food restaurants around schools: a novel application of spatial statistics to the study of food environments." <u>Am J Public Health</u> **95**(9): 1575-81.

Ball, K. and D. Crawford (2005). "Socioeconomic status and weight change in adults: a review." <u>Soc Sci Med</u> **60**(9): 1987-2010.

Barquera, S., L. Hernandez-Barrera, M. Tolentino, J. Espinosa, S. Ng, J. A. Rivera, et al. (2008). "Energy from beverages is on the rise among Mexican adolescents and adults." <u>American Journal of Clinical Nutrition</u>.

Bertheke Post, G., W. de Vente, H. C. Kemper and J. W. Twisk (2001). "Longitudinal trends in and tracking of energy and nutrient intake over 20 years in a Dutch cohort of men and women between 13 and 33 years of age: The Amsterdam growth and health longitudinal study." <u>Br J Nutr</u> **85**(3): 375-85.

Block, J. P., R. A. Scribner and K. B. DeSalvo (2004). "Fast food, race/ethnicity, and income: a geographic analysis." <u>Am J Prev Med</u> **27**(3): 211-7.

Booth, S. L., J. F. Sallis, C. Ritenbaugh, J. O. Hill, L. L. Birch, L. D. Frank, et al. (2001). "Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points." <u>Nutr Rev</u> **59**(3 Pt 2): S21-39; discussion S57-65.

Borders, T. F., J. E. Rohrer and K. M. Cardarelli (2006). "Gender-specific disparities in obesity." <u>J Community Health</u> **31**(1): 57-68.

Bouamra-Mechemache, Z., V. Réquillart, C. Soregaroli and A. Trévisiol (2008). "Demand for dairy products in the EU." <u>Food Policy</u> **33**: 644-656.

Bowman, S. A., S. Gortmaker, C. Ebbeling, M. A. Pereira and D. Ludwig (2004). "Effects of Fast-Food Consumption on Energy Intake and Diet Quality Among Children on a National Household Survey." <u>Pediatrics</u> **113**(1): 112-118.

Bowman, S. A. and B. T. Vinyard (2004). "Fast food consumption of U.S. Adults: impact on energy and nutrient intakes and overweight status." <u>J Am Coll Nutr</u> **23**(2): 163-8.

Bureau of Labor Statistics. (2001, October 16). "Consumer Price Index." Retrieved January 24, 2009, from http://www.bls.gov/cpi/cpiovrvw.htm.

<center>81</center>

Burton, S., E. Creyer, J. Kees and K. Huggins (2006). "Attacking the obesity epidemic: the potential health benefits of providing nutrition information in restaurants. ." Am J Public Health **96**(9): 1669-1675.

C2ER. (2008). "Council for Community and Economic Research."   Retrieved September, 24, 2008, from http://www.c2er.org/.

Caraher, M. and G. Cowburn (2005). "Taxing food: implications for public health nutrition." Public Health Nutr **8**(8): 1242-9.

Cardello, H. and D. Garr ((In Press) 2009). Stuffed: An insider's look at who's (really) making America fat, Harper Collins.

CARDIA. (2009). "CARDIA website: Overview, publications, and exam components." Retrieved January 21, 2009, from http://www.cardia.dopm.uab.edu/overview.htm.

Cash, S., D. Sunding and D. Zilberman (2005). "Fat taxes and thin subsidies: Prices, diet, and health outcomes." Acta Agriculturae Scandinavica, Section C - Economy **2**(3-4): 167-174(8).

Cassano, P. A., B. Rosner, P. S. Vokonas and S. T. Weiss (1992). "Obesity and body fat distribution in relation to the incidence of non-insulin-dependent diabetes mellitus. A prospective cohort study of men in the normative aging study." Am J Epidemiol **136**(12): 1474-86.

Cavadini, C., A. M. Siega-Riz and B. Popkin (2000). "US adolescent food intake trends from 1965 to 1996." Arch Dis Child **83**: 18-24.

Center for Science in the Public Interest. (2006). "CSPI Withdraws From Lawsuit After KFC Cuts Trans Fat."   Retrieved February 6, , 2008, from http://www.cspinet.org/new/200610301.html.

Chaloupka, F. J., K. M. Cummings, C. P. Morley and J. K. Horan (2002). "Tax, price and cigarette smoking: evidence from the tobacco documents and implications for tobacco company marketing strategies." Tob Control **11 Suppl 1**: I62-72.

Chaloupka, F. J., K. M. Cummings, C. P. Morley and J. K. Horan (2002). "Tax, price and cigarette smoking: evidence from the tobacco documents and implications for tobacco company marketing strategies." Tobacco Control **11 Suppl 1**: I62-72.

Chan, S. (2008). "Soda Tax Plan Sparks a Debate."   Retrieved December 30, 2008, from http://cityroom.blogs.nytimes.com/2008/12/16/soda-tax-plan-sparks-a-debate/?scp=1&sq=Beverage%20Tax&st=cse.

Chouinard, H., D. Davis, J. LaFrance and J. Perloff (2007). "Fat Taxes: Big Money for Small Change." Fat Taxes: Big Money for Small Change **10**(2): 1-30 (article 2).

Chung, C. and S. Myers (1999). "Do the Poor Pay More for Food? An Analysis of Grocery Store Availability and Food Price Disparities." The Journal of Consumer Affairs **33**(2): 276-296.

Croll, J. K., D. Neumark-Sztainer and M. Story (2001). "Healthy eating: what does it mean to adolescents?" J Nutr Educ **33**(4): 193-8.

Cummins, S., M. Stafford, S. Macintyre, M. Marmot and A. Ellaway (2005). "Neighbourhood environment and its association with self rated health: evidence from Scotland and England." J Epidemiol Community Health **59**(3): 207-13.

Darmon, N., M. Darmon, M. Maillot and A. Drewnowski (2005). "A nutrient density standard for vegetables and fruits: nutrients per calorie and nutrients per unit cost." J Am Diet Assoc **105**(12): 1881-7.

Darmon, N. and A. Drewnowski (2008). "Does social class predict diet quality?" Am J Clin Nutr **87**(5): 1107-17.

Darmon, N., E. L. Ferguson and A. Briend (2002). "A cost constraint alone has adverse effects on food selection and nutrient density: an analysis of human diets by linear programming." J Nutr **132**(12): 3764-71.

de Wit, L. M., A. van Straten, M. van Herten, B. W. Penninx and P. Cuijpers (2009). "Depression and Body Mass Index, a U-shaped association." BMC Public Health **9**(1): 14.

Dhingra, R., L. Sullivan, P. F. Jacques, T. J. Wang, C. S. Fox, J. B. Meigs, et al. (2007). "Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community." Circulation **116**(5): 480-8.

Diliberti, N., P. L. Bordi, M. T. Conklin, L. S. Roe and B. J. Rolls (2004). "Increased portion size leads to increased energy intake in a restaurant meal." Obes Res **12**(3): 562-8.

Douketis, J. D., C. Macie, L. Thabane and D. F. Williamson (2005). "Systematic review of long-term weight loss studies in obese adults: clinical significance and applicability to clinical practice." Int J Obes (Lond) **29**(10): 1153-67.

Drewnowski, A. and N. Darmon (2005). "The economics of obesity: dietary energy density and energy cost." Am J Clin Nutr **82**(1 Suppl): 265S-273S.

Drewnowski, A. and N. Darmon (2005). "Food choices and diet costs: an economic analysis." J Nutr **135**(4): 900-4.

Drewnowski, A., N. Darmon and A. Briend (2004). "Energy-dense diets are associated with lower diet costs: a community study of French adults." Public Health Nutr **7**(1): 21-7.

Duffey, K., P. Gordon-Larsen, Jacobs DJ and B. M. Popkin (2007). Away from home eating and 13-year weight gain: The CARDIA Study (Abstract). Experimental Biology, Washington, DC.

Duffey, K. J., P. Gordon-Larsen, D. R. Jacobs, Jr., O. D. Williams and B. M. Popkin (2007). "Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the Coronary Artery Risk Development in Young Adults Study." <u>Am J Clin Nutr</u> **85**(1): 201-8.

Duffey, K. J., P. Gordon-Larsen, D. R. Jacobs, Jr., O. D. Williams and B. M. Popkin (2007). "Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the Coronary Artery Risk Development in Young Adults Study." <u>American Journal of Clinical Nutrition</u> **85**(1): 201-8.

Dunn, J. E., K. Liu, P. Greenland, J. E. Hilner and D. R. Jacobs, Jr. (2000). "Seven-year tracking of dietary factors in young adults: the CARDIA study." <u>Am J Prev Med</u> **18**(1): 38-45.

Dyer, A. R., K. Liu, M. Walsh, C. Kiefe, D. R. Jacobs, Jr. and D. E. Bild (1999). "Ten-year incidence of elevated blood pressure and its predictors: the CARDIA study. Coronary Artery Risk Development in (Young) Adults." <u>J Hum Hypertens</u> **13**(1): 13-21.

Eisenhauer, E. (2001). "In poor health: Supermarket redlining and urban nutrition." <u>Geo Journal</u> **53**(2): 125-133.

Epstein, L. H., K. K. Dearing, R. A. Paluch, J. N. Roemmich and D. Cho (2007). "Price and maternal obesity influence purchasing of low- and high-energy-dense foods." <u>Am J Clin Nutr</u> **86**(4): 914-22.

Epstein, L. H., E. A. Handley, K. K. Dearing, D. D. Cho, J. N. Roemmich, R. A. Paluch, et al. (2006). "Purchases of food in youth. Influence of price and income." <u>Psychol Sci</u> **17**(1): 82-9.

Felber, J. P. and A. Golay (2002). "Pathways from obesity to diabetes." <u>Int J Obes Relat Metab Disord</u> **26 Suppl 2**: S39-45.

Finkelstein, D. M., E. L. Hill and R. C. Whitaker (2008). "School food environments and policies in US public schools." <u>Pediatrics</u> **122**(1): e251-9.

Finkelstein, E., S. French, J. N. Variyam and P. S. Haines (2004). "Pros and cons of proposed interventions to promote healthy eating." <u>Am J Prev Med</u> **27**(3 Suppl): 163-71.

Flegal, K. M. (2005). "Epidemiologic aspects of overweight and obesity in the United States." <u>Physiol Behav</u> **86**(5): 599-602.

Flegal, K. M., B. I. Graubard, D. F. Williamson and M. H. Gail (2005). "Excess deaths associated with underweight, overweight, and obesity." <u>Jama</u> **293**(15): 1861-7.

Freedman, D. S., L. K. Khan, M. K. Serdula, W. H. Dietz, S. R. Srinivasan and G. S. Berenson (2004). "Inter-relationships among childhood BMI, childhood height, and adult obesity: the Bogalusa Heart Study." <u>Int J Obes Relat Metab Disord</u> **28**(1): 10-6.

Freedman, D. S., L. K. Khan, M. K. Serdula, W. H. Dietz, S. R. Srinivasan and G. S. Berenson (2005). "Racial differences in the tracking of childhood BMI to adulthood." Obes Res **13**(5): 928-35.

French, S. (2003). "Pricing Effects on Food Choices." J Nutr **133**: 841S-843S.

French, S., L. Harnack and R. Jeffery (2000). "Fast food restaurant use among women in the Pound of Prevention study: dietary, behavioral and demographic correlates." Int J Obes Relat Metab Disord **24**(10): 1353-1359.

French, S., R. Jeffery, M. Story, K. Breitlow, J. Baxter, P. Hannan, et al. (2001). "Pricing and Promotion Effects on Low-Fat Vending Snack Purchases: The CHIPS Study." Am J Public Health **91**(1): 112-117.

French, S., M. Story and R. Jeffery (2001). "Environmental Influences on Eating and Physical Activity." Annu Rev Public Health **22**: 309-335.

French, S., M. Story, D. Neumark-Sztainer, J. Fulkerson and P. Hannan (2001). "Fast food restaurant use among adolescents: associations with nutirent intake, food choice, and behavioral and psycholsocial variables." Int J Obes **25**: 1823-1833.

Friedewald, W., Levy ,RI, Fredrickson, DS. (1972). "Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge." Clin Chem **18**: 499 –502.

Friedman, G., G. Cutter, R. Donahue, G. Hughes, S. Hulley, D. Jacobs, et al. (1988). "CARDIA: Study design, recruitment, and some characteristics of the examined subjects." J Clin Epidemiol **41**: 1105-16.

Garrison, R. J., W. B. Kannel, J. Stokes, 3rd and W. P. Castelli (1987). "Incidence and precursors of hypertension in young adults: the Framingham Offspring Study." Prev Med **16**(2): 235-51.

Ginsberg, H. N., Y. L. Zhang and A. Hernandez-Ono (2006). "Metabolic syndrome: focus on dyslipidemia." Obesity (Silver Spring) **14 Suppl 1**: 41S-49S.

Glanz, K., M. Basil, E. Maibach, J. Goldberg and D. Snyder (1998). "Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption." J Am Diet Assoc **98**(10): 1118-26.

Glanz, K., K. Resnicow, J. Seymour, K. Hoy, H. Stewart, M. Lyons, et al. (2007). "How major restaurant chains plan their menus: the role of profit, demand, and health." Am J Prev Med **32**(5): 383-8.

Goldstein, D. J. (1992). "Beneficial health effects of modest weight loss." Int J Obes Relat Metab Disord **16**(6): 397-415.

Goran, M. I., G. D. Ball and M. L. Cruz (2003). "Obesity and risk of type 2 diabetes and cardiovascular disease in children and adolescents." J Clin Endocrinol Metab **88**(4): 1417-27.

Gordon-Larsen, P., L. S. Adair, M. C. Nelson and B. M. Popkin (2004). "Five-year obesity incidence in the transition period between adolescence and adulthood: the National Longitudinal Study of Adolescent Health." Am J Clin Nutr **80**(3): 569-75.

Gordon-Larsen, P., L. S. Adair and B. M. Popkin (2002). "Ethnic differences in physical activity and inactivity patterns and overweight status." Obes Res **10**(3): 141-9.

Gordon-Larsen, P., L. S. Adair and B. M. Popkin (2003). "The relationship of ethnicity, socioeconomic factors, and overweight in US adolescents." Obes Res **11**(1): 121-9.

Gordon-Larsen, P., M. C. Nelson, P. Page and B. M. Popkin (2006). "Inequality in the built environment underlies key health disparities in physical activity and obesity." Pediatrics **117**(2): 417-24.

Gray, L. and A. H. Leyland (2008). "Overweight status and psychological well-being in adolescent boys and girls: a multilevel analysis." Eur J Public Health **18**(6): 616-21.

Grossman, M. and F. J. Chaloupka (1997). "Cigarette taxes. The straw to break the camel's back." Public Health Reports **112**(4): 290-7.

Grossman, M. and F. J. Chaloupka (1997). "Cigarette taxes. The straw to break the camel's back." Public Health Reports **112**(4): 290-7.

Guagnano, M. T., E. Ballone, V. Colagrande, R. Della Vecchia, M. R. Manigrasso, D. Merlitti, et al. (2001). "Large waist circumference and risk of hypertension." Int J Obes Relat Metab Disord **25**(9): 1360-4.

Guthrie, J. F., B. H. Lin and E. Frazao (2002). "Role of food prepared away from home in the American diet, 1977-78 versus 1994-96: changes and consequences." J Nutr Educ Behav **34**(3): 140-50.

Heitmann, B. L. and P. Frederiksen (2007). "Imprecise methods may both obscure and aggravate a relation between fat and breast cancer." Eur J Clin Nutr **61**(7): 925-7.

Heitmann, B. L. and L. Lissner (2005). "Can adverse effects of dietary fat intake be overestimated as a consequence of dietary fat underreporting?" Public Health Nutr **8**(8): 1322-7.

Horgen, K. B. and K. D. Brownell (2002). "Comparison of price change and health message interventions in promoting healthy food choices." Health Psychol **21**(5): 505-12.

Horovitz, B. (2006). KFC plans important trans fat milestone. . USA Today.

Huang, K. and H. Bouis (1996). Structural changes in the Demand for Food in Asia" Food, Agriculture and the Environment discussion paper 11. Washington DC, International Food Policy Research Institute**: 1-23.

Huang, K. S. (1997). "Nutrient elasiticities in a complete food demand system." Am J Agric Econ. **78**(1): 21-29.

Huang, K. S. (1997). " Nutrient Elasticities in a complete food demand system." Am J Agric Econ. **78**: 21-29.

Huang, Z., W. C. Willett, J. E. Manson, B. Rosner, M. J. Stampfer, F. E. Speizer, et al. (1998). "Body weight, weight change, and risk for hypertension in women." Ann Intern Med **128**(2): 81-8.

Hughes, G. H., G. Cutter, R. Donahue, G. D. Friedman, S. Hulley, E. Hunkeler, et al. (1987). "Recruitment in the Coronary Artery Disease Risk Development in Young Adults (Cardia) Study." Control Clin Trials **8**(4 Suppl): 68S-73S.

Hulshof, K. F., J. H. Brussaard, A. G. Kruizinga, J. Telman and M. R. Lowik (2003). "Socio-economic status, dietary intake and 10 y trends: the Dutch National Food Consumption Survey." Eur J Clin Nutr **57**(1): 128-37.

Inglis, V., K. Ball and D. Crawford (2005). "Why do women of low socioeconomic status have poorer dietary behaviours than women of higher socioeconomic status? A qualitative exploration." Appetite **45**(3): 334-43.

Jacobs, D., L. Hahn, W. Haskell, P. Pirie and S. Sidney (1989). "Validity and reliability of short phsyical activity history: CARDIA and the Minnesota Heart Healthy Program." J Cardiopulmonary Rehab **9**: 448-459.

Jacobson, M. and K. Brownell (2000). "Small Taxes on Soft Drinks and Snack Foods to Promote Health." Am J Public Health **90**(6): 854-857.

Jeffery, R. and S. French (1998). "Epidemic Obesity in the United States: Are Fast Food and Television Viewing Contributing?" Am J Public Health **88**(2): 277-280.

Jeffery, R., S. French, C. Raether and J. Baxter (1994). "An environmental intervention to increase fruit and salad purchases in a cafeteria." Prev Med **23**(6): 788-92.

Jeffery, R. and J. Utter (2003). "The Changing Environment and Population Obesity in the United States." Obes Res **11**: 12S-22S.

Kahn, S. E., R. L. Hull and K. M. Utzschneider (2006). "Mechanisms linking obesity to insulin resistance and type 2 diabetes." Nature **444**(7121): 840-6.

Kamphuis, C. B., F. J. van Lenthe, K. Giskes, J. Brug and J. P. Mackenbach (2007). "Perceived environmental determinants of physical activity and fruit and vegetable

consumption among high and low socioeconomic groups in the Netherlands." Health Place **13**(2): 493-503.

Kant, A. K. and B. I. Graubard (2004). "Eating out in America, 1987-2000: trends and nutritional correlates." Prev Med **38**(2): 243-9.

Kekalainen, P., H. Sarlund and M. Laakso (2000). "Long-term association of cardiovascular risk factors with impaired insulin secretion and insulin resistance." Metabolism **49**(10): 1247-54.

Koh-Banerjee, P., N. F. Chu, D. Spiegelman, B. Rosner, G. Colditz, W. Willett, et al. (2003). "Prospective study of the association of changes in dietary intake, physical activity, alcohol consumption, and smoking with 9-y gain in waist circumference among 16 587 US men." Am J Clin Nutr **78**(4): 719-27.

Kruger, J., H. R. Bowles, et al. (2006). "." Int J Obes (Lond). (2007). "Health-related quality of life, BMI and physical activity among US adults (>/=18 years): National Physical Activity and Weight Loss Survey, 2002." Int J Obes (Lond) **31**(2): 321-7.

Laakso, M., H. Sarlund and L. Mykkanen (1990). "Insulin resistance is associated with lipid and lipoprotein abnormalities in subjects with varying degrees of glucose tolerance." Arteriosclerosis **10**(2): 223-31.

Laraia, B. A., A. M. Siega-Riz, J. S. Kaufman and S. J. Jones (2004). "Proximity of supermarkets is positively associated with diet quality index for pregnancy." Prev Med **39**(5): 869-75.

Liang, L., F. Chaloupka, M. Nichter and R. Clayton (2003). "Prices, policies and youth smoking, May 2001." Addiction **98 Suppl 1**: 105-22.

Lillie-Blanton, M., P. E. Parsons, H. Gayle and A. Dievler (1996). "Racial differences in health: not just black and white, but shades of gray." Annu Rev Public Health **17**: 411-48.

Lin, B., E. Frazao and G. JF (1999). Away-From-Home Foods increasingly important to quality of American diet. E. S. Research, United States Department of Agriculture.

Lin, B. H., C. L. Huang and S. A. French (2004). "Factors associated with women's and children's body mass indices by income status." Int J Obes Relat Metab Disord **28**(4): 536-42.

Lindstrom, J., M. Peltonen, J. G. Eriksson, A. Louheranta, M. Fogelholm, M. Uusitupa, et al. (2006). "High-fibre, low-fat diet predicts long-term weight loss and decreased type 2 diabetes risk: the Finnish Diabetes Prevention Study." Diabetologia **49**(5): 912-20.

Liu, G., C. Cunningham, S. Downs, D. Marrero and N. Fineberg (2002). "A spatial analysis of obesogenic environments for children." Proceedings/ AMIA..Annual Symposium: 459-463.

Liu, K., M. L. Slattery, D. R. Jacobs, Jr., G. Cutter, A. McDonald, L. Van Horn, et al. (1994). "A study of the reliability and comparative validity of the CARDIA dietary history." Ethnicity Dis **4**: 15-27.

MacDonald, J. M. and P. Nelson Jr. (1991). "Do the poor still pay more? Food price variations in large metropolitan areas." Journal of Urban Economics **30**(3): 344-359.

Matthews, D., J. Hosker, A. Rudenski, B. Naylor, D. Treacher and T. Turner (1985). " Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man." Diabetologia **28**: 412-419.

Mayer-Davis, E. J. (2008). "Type 2 diabetes in youth: epidemiology and current research toward prevention and treatment." J Am Diet Assoc **108**(4 Suppl 1): S45-51.

McCrory, M., P. Fuss, N. Hays, A. Vinken, A. Greenberg and S. Roberts (1999). "Overeating in America: association between restaurant food consumption and body fatness in healthy men and women ages 19 to 80." Obes Res **7**(6): 564-571.

McCrory, M. A., P. J. Fuss, E. Saltzman and S. B. Roberts (2000). "Dietary determinants of energy intake and weight regulation in healthy adults." J Nutr **130**(2S Suppl): 276S-279S.

McDonald, A., L. Van Horn, M. Slattery, J. Hilner, C. Bragg, B. Caan, et al. (1991). "The CARDIA dietary history: development, implementation, and evaluation." J Am Diet Assoc **91**(9): 1104-12.

McKinley, J. (2007). "San Francisco's Mayor Proposes Fee on Sales of Sugary Soft Drinks " Retrieved December 30, 2008, from http://www.nytimes.com/2007/12/18/us/18soda.html.

McTigue, K., J. Garrett and B. Popkin (2003). "The Natural Hisorty of the Development of Obesity in a Cohort of Young U.S. Adults between 1981 and 1998." Ann Intern Med **136**(12): 857-864.

Mincer, J. (1963). Market prices, oppurtunity costs, and income effects. Measurement in economics: studies in mathematical economics and econometrics in memory of Yehuda Grunfeld. C. F. Christ, M. Friedman, L. A. Goodmanet al. Stanford, CA, Stanford University Press.

Mooney, C. (1990). "Cost and availability of healthy food choices in a London health district." J Hum Nutr Diet **3**: 111-120.

Moore, L. V. and A. V. Diez Roux (2006). "Associations of neighborhood characteristics with the location and type of food stores." Am J Public Health **96**(2): 325-31.

Morland, K., S. Wing and A. Diez Roux (2002). "The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study." Am J Public Health **92**(11): 1761-7.

Morland, K., S. Wing, A. Diez Roux and C. Poole (2002). "Neighborhood characteristics associated with the location of food stores and food service places." Am J Prev Med **22**(1): 23-9.

Murakami, K., S. Sasaki, H. Okubo, Y. Takahashi, Y. Hosoi and M. Itabashi (2007). "Monetary costs of dietary energy reported by young Japanese women: association with food and nutrient intake and body mass index." Public Health Nutr: 1-10.

Must, A., J. Spadano, E. H. Coakley, A. E. Field, G. Colditz and W. H. Dietz (1999). "The disease burden associated with overweight and obesity." Jama **282**(16): 1523-9.

National Institutes of Health (1998). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. Bethesda, MD, NHLBI.

Nayga, R. J. and Z. Weinberg (1999). "Supermarket access in the inner cities " Journal of Retailing and Consumer Services **6**(3): 141-45.

Neumark-Sztainer, D., M. Wall, C. Perry and M. Story (2003). "Correlates of fruit and vegetable intake among adolescents. Findings from Project EAT." Prev Med **37**(3): 198-208.

Ng, S. W., F. Zhai and B. M. Popkin (2008). "Impacts of China's edible oil pricing policy on nutrition." Soc Sci Med **66**(2): 414-26.

NHLBI (2002). Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). S. M. Grundy, chair Bethesda, MD, NIH Publication No. 02-5215, National Cholesterol Education Program; National Heart, Lung, and Blood Institute; National Institutes of Health.

Nielsen, S. and B. Popkin (2003). "Patterns and Trends in Portion Sizes, 1977-1998." JAMA **289**(4): 450-453.

Nielsen, S., A. Siega-Riz and B. Popkin (2002). "Trends in Energy Intake in the U.S. between 1977 and 1996: Similar Shifts Seen Across Age Groups." Obes Res **10**(5): 370-378.

Nielsen, S., A. Siega-Riz and B. Popkin (2002). "Trends in Food Locations and Sources Among Adolescents and Young Adults." Preventive Medicine **35**: 107-113.

Ogden, C., M. D. Carroll and K. Flegal (2008). "High Body Mass Index for Age Among US Children and Adolescents, 2003-2006." JAMA **299**(20): 2401-2405.

Ogden, C. L., M. D. Carroll, L. R. Curtin, M. A. McDowell, C. J. Tabak and K. M. Flegal (2006). "Prevalence of overweight and obesity in the United States, 1999-2004." Jama **295**(13): 1549-55.

Ogden, C. L., S. Z. Yanovski, M. D. Carroll and K. M. Flegal (2007). "The epidemiology of obesity." Gastroenterology **132**(6): 2087-102.

Paeratakul, S., D. P. Ferdinand, C. M. Champagne, D. H. Ryan and G. A. Bray (2003). "Fast-food consumption among US adults and children: dietary and nutrient intake profile." J Am Diet Assoc **103**(10): 1332-8.

Parillo, M. and G. Riccardi (2004). "Diet composition and the risk of type 2 diabetes: epidemiological and clinical evidence." Br J Nutr **92**(1): 7-19.

Pearce, J., T. Blakely, K. Witten and P. Bartie (2007). "Neighborhood deprivation and access to fast-food retailing: a national study." Am J Prev Med **32**(5): 375-82.

Pereira, M. A., A. I. Kartashov, C. B. Ebbeling, L. Van Horn, M. L. Slattery and D. R. Jacobs, Jr. (2005). "Fast-food habits, weight gain and insulin resistance (the CARDIA) study: 15-year prospective analysis." Lancet **365**(9453): 36-42.

Pesce, M. and S. Bodourian (1976). "Enzymatic Rate Method for Measuring Cholesterol in Serum." Clin Chem **22**: 2042-45.

Pickett, K. E. and M. Pearl (2001). "Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review." J Epidemiol Community Health **55**(2): 111-22.

Popkin, B. M. (2008). The World Is Fat--The Fads, Trends, Policies, and Products That Are Fattening the Human Race. New York, Avery-Penguin Group.

Popkin, B. M., K. Duffey and P. Gordon-Larsen (2005). "Environmental influences on food choice, physical activity and energy balance." Physiol Behav **86**(5): 603-13.

Prentice, A. M. and S. A. Jebb (2003). "Fast food and energy density: a possible mechanistic link." Obesity Reviews **4**: 187-194.

Prentice, A. M. and S. A. Jebb (2003). "Fast foods, energy density and obesity: a possible mechanistic link." Obes Rev **4**(4): 187-94.

Quatromoni, P. A., D. L. Copenhafer, R. B. D'Agostino and B. E. Millen (2002). "Dietary patterns predict the development of overweight in women: The Framingham Nutrition Studies." J Am Diet Assoc **102**(9): 1239-46.

Reaven, G. M. (1997). "Banting Lecture 1988. Role of insulin resistance in human disease. 1988." Nutrition **13**(1): 65; discussion 64, 66.

Reaven, G. M. (2008). "Insulin resistance: the link between obesity and cardiovascular disease." Endocrinol Metab Clin North Am **37**(3): 581-601, vii-viii.

Reidpath, D. D., C. Burns, J. Garrard, M. Mahoney and M. Townsend (2002). "An ecological study of the relationship between social and environmental determinants of obesity." Health Place **8**(2): 141-5.

Robert, S. A. and E. N. Reither (2004). "A multilevel analysis of race, community disadvantage, and body mass index among adults in the US." Soc Sci Med **59**(12): 2421-34.

Robert, S. A. and E. N. Reither (2004). "A multilevel analysis of race, community disadvantage, and body mass index among adults in the US " Soc Sci Med **59**(12): 2421-34.

Rosenheck, R. (2008). "Fast food consumption and increased caloric intake: a systematic review of a trajectory towards weight gain and obesity risk." Obes Rev **9**: 535-47.

Satia, J., J. Galanko and A. M. Siega-Riz (2004). "Eating at fast-food restaurants is associated with dietary intake, demographic, psychosocial and behavioral factors among African Americans in North Carolina." Public Health Nutr **7**(8): 1089-1096.

Schienkiewitz, A., M. B. Schulze, K. Hoffmann, A. Kroke and H. Boeing (2006). "Body mass index history and risk of type 2 diabetes: results from the European Prospective Investigation into Cancer and Nutrition (EPIC)-Potsdam Study." Am J Clin Nutr **84**(2): 427-33.

Schmidt, M., S. G. Affenito, R. Striegel-Moore, P. R. Khoury, B. Barton, P. Crawford, et al. (2005). "Fast-food intake and diet quality in black and white girls: the National Heart, Lung, and Blood Institute Growth and Health Study." Arch Pediatr Adolesc Med **159**(7): 626-31.

Schroder, H., M. Fito and M. Isabel Covas (2007). "Association of fast food consumption with energy intake, diet quality, body mass index and the risk of obesity in a representative Mediterranean population." Br J Nutr: 1-7.

Schroder, H., Marrugat, J., Covas, M.I. (2006). "High monetary costs of dietary patterns associated with lower body mass index: A population-based study " Int J Obes **30**(10): 1574-1579.

Schroeter, C., J. Lusk and W. Tyner (2008). "Determining the impact of food price and income changes on body weight." J Health Econ **27**(1): 45-68.

Schulze, M. B., J. E. Manson, D. S. Ludwig, G. A. Colditz, M. J. Stampfer, W. C. Willett, et al. (2004). "Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women." JAMA **292**(8): 927-34.

Serdula, M. K., D. Ivery, R. J. Coates, D. S. Freedman, D. F. Williamson and T. Byers (1993). "Do obese children become obese adults? A review of the literature." Prev Med **22**(2): 167-77.

Slattery, M. L., A. Dyer, D. R. Jacobs, Jr., J. E. Hilner, B. Caan, D. E. Bild, et al. (1994). "A comparison of two methods to ascertain dietary intake: the CARDIA study." J Clin Epidemiol **47**(7): 701-711.

Smiciklas-Wright, H., D. C. Mitchell, S. J. Mickle, J. D. Goldman and A. Cook (2003). "Foods commonly eaten in the United States, 1989-1991 and 1994-1996: are portion sizes changing?" J Am Diet Assoc **103**(1): 41-7.

Sobal, J. and A. J. Stunkard (1989). "Socioeconomic status and obesity: a review of the literature." Psychol Bull **105**(2): 260-75.

Stender, S., J. Dyerberg and A. Astrup (2007). "Fast food: unfriendly and unhealthy." Int J Obes (Lond) **31**(6): 887-90.

Stewart, H., N. Blisard, S. Bhuyan and R. Naya (2004). The Demand for Food Away From Home: Full Service or Fast Food? U.S. Department of Agriculture Economic Research Services.

Stewart, H., N. Blisard and D. Jolliffe (2003). "Do Income Constraints Inhibit Spending on Fruits and Vegetables Among Low-Income Households?" Journal of Agricultural and Resource Economics **28**(3): 465-480.

Story, M., D. Neumark-Sztainer and S. French (2002). "Individual and environmental influences on adolescent eating behaviors." J Am Diet Assoc **102**(3 Suppl): S40-51.

Thompson, O., C. Ballew, K. Resnicow, A. Must, L. Bandini, H. Cyr, et al. (2004). "Food purchased away from home as a predictor of change in BMI z-scores among girls." International Journal of Obesity **28**: 282-289.

Variyam, J. N. (2008). "Do nutrition labels improve dietary outcomes?" Health Econ **17**(6): 695-708.

Vartanian, L. R., M. B. Schwartz and K. D. Brownell (2007). "Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis." American Journal of Public Health **97**(4): 667-75.

Vazquez, G., S. Duval, D. R. Jacobs, Jr. and K. Silventoinen (2007). "Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis." Epidemiol Rev **29**: 115-28.

von Braun, J., with Ahmed,Akhter , Asenso-Okyere, Kwadwo, Fan, Shenggen,Gulati,Ashok ,Hoddinott, John,   Pandya-Lorch,Rajul, . Rosegrant,Mark W ,Ruel,Marie, Torero, Maximo, van Rheenen, Teunisand, von Grebmer,Klaus (2008). High Food Prices:The What, Who, and How of Proposed Policy Actions Policy Brief. IFPRI. Washington DC, IFPRI.

Wakefield, M. A., S. Durkin, M. J. Spittal, M. Siahpush, M. Scollo, J. A. Simpson, et al. (2008). "Impact of tobacco control policies and mass media campaigns on monthly adult smoking prevalence." Am J Public Health **98**(8): 1443-50.

Warner, K. E. (2005). Tobacco Policy in the United States: Lessons for the Obesity Epidemic. Policy Challenges in Modern Health Care. D. Mechanic, L. B. Rogut, D. C. Colby and J. R. Knickman. New Brunswick, NJ, Rutgers University Press**:** 99-114.

Warnick, G. R., J. Benderson and J. J. Albers (1982). "Dextran sulfate-Mg2+ precipitation procedure for quantitation of high-density-lipoprotein cholesterol." Clin Chem **28**(6): 1379-88.

WHO (2000). Obesity: preventing and managing the global epidemic. Report of a WHO consultation. <u>World Health Organ Tech Rep Ser</u>. **894:** i-xii, 1-253.

WHO/FAO (2003). <u>Expert Consultation on Diet, Nutrition and the Prevention of Chronic DiseasesReport of the joint WHO/FAO expert consultation</u>. Geneva, World Health Organization.

Willett, W. (1998). <u>Nutritional Epidemiology, 2nd edition</u>. New York, NY, Oxford University Press.

Williams, D. R. (1997). "Race and health: basic questions, emerging directions." <u>Ann Epidemiol</u> **7**(5): 322-33.

Wing, R. R., R. Koeske, L. H. Epstein, M. P. Nowalk, W. Gooding and D. Becker (1987). "Long-term effects of modest weight loss in type II diabetic patients." <u>Arch Intern Med</u> **147**(10): 1749-53.

Wood, P., Stefanick, ML., Dreon, DM., , B. Frey-Hewitt, S. Garay, P. Williams, H. Superko, S. Fortmann, et al. (1988). "Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise." <u>N Engl J Med </u>**319**: 1173-9.

World Cancer Research Fund / American Institute for Cancer Research (2007). Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective. Washington, DC, AICR.

Wu, Y., E. Li and N. Samuel (1995). "Food consumption in urban China: an empirical analysis." <u>Applied Economics</u> **v27**(n6): p509(7).

Young, L. R. and M. Nestle (2002). "The contribution of expanding portion sizes to the US obesity epidemic." <u>Am J Public Health</u> **92**(2): 246-9.

Zhu, S., Z. Wang, S. Heshka, M. Heo, M. S. Faith and S. B. Heymsfield (2002). "Waist circumference and obesity-associated risk factors among whites in the third National Health and Nutrition Examination Survey: clinical action thresholds." <u>Am J Clin Nutr</u> **76**(4): 743-9.