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Multiple pathways from the neighborhood food environment to increased body mass index through dietary behaviors: A structural equation-based analysis in the CARDIA study

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ABSTRACT

Objectives: To examine longitudinal pathways from multiple types of neighborhood restaurants and food stores to BMI, through dietary behaviors.
Methods: We used data from participants ($n=5114$) in the United States-based Coronary Artery Risk Development in Young Adults study and a structural equation model to estimate longitudinal (1985–86 to 2005–06) pathways simultaneously from neighborhood fast food restaurants, sit-down restaurants, supermarkets, and convenience stores to BMI through dietary behaviors, controlling for socioeconomic status (SES) and physical activity.
Results: Higher numbers of neighborhood fast food restaurants and lower numbers of sit-down restaurants were associated with higher consumption of an obesogenic fast food-type diet. The pathways from food stores to BMI through diet were inconsistent in magnitude and statistical significance.
Conclusions: Efforts to decrease the numbers of neighborhood fast food restaurants and to increase the numbers of sit-down restaurant options could influence diet behaviors. Availability of neighborhood fast food and sit-down restaurants may play comparatively stronger roles than food stores in shaping dietary behaviors and BMI.

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1. Introduction

Since the mid-1980's, obesity increased dramatically across developed countries, such as the U.S., U.K., New Zealand, and Canada (World Health Organization, 2011) with socioeconomically disadvantaged populations disproportionately affected (McLaren, 2007; Ministry of Health, 2004). At the same time, a literature (albeit somewhat mixed) has developed suggesting a role for neighborhood SES in the availability of healthy foods, with lower SES communities having comparatively lower access to higher quality food sources (Block et al., 2004; Moore and Diez Roux, 2006; Morland and Filomena, 2007). Consequently, efforts to improve dietary behaviors and reduce obesity have targeted neighborhood restaurants, especially fast food restaurants, and lack of quality food stores in disadvantaged areas (Let's Move, 2012; The Food Trust, 2004). Yet, most of the evidence is based on cross-sectional studies that focused on a single part of the pathway, either direct associations for food stores and restaurants with

Abbreviations: BMI, Body mass index; CARDIA, Coronary Artery Risk Development in Young Adults; CFI, Comparative fit index; kg, kilogram; m, meter; SEM, Structural equation modeling; SES, Socioeconomic status; SD, Standard deviation; SSB, Sugar-sweetened beverage; RMSEA, Root mean square error approximation; TLI, Tucker–Lewis Index

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dietary behaviors *or* with body mass index (BMI) (Caspi et al., 2012; Giskes et al., 2011). The extent to which changing food environments lead to individual-level dietary change and consequent reduction in obesity, through diet, is unknown.

International researchers suggest that comprehensive strategies are needed to address environmental and societal factors to reduce obesity disparities (Foresight, 2007; World Health Organization, 2013) Yet, socioeconomically disadvantaged subpopulations in developed countries remain disproportionately affected by obesity (McLaren, 2007; Ministry of Health, 2004). Thus, researchers have begun to examine how temporal changes in food environments impact diet and obesity (Burgoine et al., 2009; Cummins et al., 2014; Smith et al., 2010). But findings are mixed and studies examining temporal patterns in food environments are sparse [see review (Mackenbach et al., 2014)]. A large gap remains in long-term, population-based research in racially diverse samples with detailed time-varying food environment data.

Cross-sectional studies cannot link changes in neighborhood environments with changes in individual-level diet and body weight (Gary-Webb et al., 2010). The few longitudinal studies (Block et al., 2011; Boone-Heinonen et al., 2011; Gibson, 2011) have generally examined associations between a single type of restaurant or food store with a single outcome, such as BMI, obesity, or a broad diet behavior (e.g., diet quality) (Moore et al., 2009). Moreover, we posit that food stores and restaurants do not influence dietary behaviors in isolation; rather, alternative food resources within the same neighborhood may also be important. New approaches to modeling complex pathways that simultaneously account for multiple food store and restaurant options may help explain inconsistent findings in the literature on neighborhood environment and BMI (Ball et al., 2012; Mackenbach et al., 2014).

While neighborhood food stores and restaurants may influence obesity indirectly through dietary behaviors, presence of neighborhood food stores and restaurants may also relate to other neighborhood resources, such as street networks, presence of parks or other obesity-related amenities (Belon et al., 2014; Tseng et al., 2014). This necessitates control for a variety of other neighborhood characteristics through pathway-based approaches. Yet, a majority of research ignores complex pathways, instead using simple direct association. Use of simultaneous regression modeling via systems of equations may help clarify hypothesized pathways.

We used a single longitudinal structural equation model (SEM) in a large United States (U.S.)-based prospective cohort of adult black and white adults over 20 years to estimate simultaneous and separate pathways from neighborhood fast food restaurants, sit-down restaurants, supermarkets and convenience stores to individual-level diet behaviors and BMI. We have two central hypotheses: **Hypothesis 1:** neighborhood restaurants and food stores are indirectly associated with BMI through the consumption of specific foods typically acquired from specific types of restaurants and foods stores; and **Hypothesis 2:** associations between restaurants and food stores with dietary behaviors and BMI become stronger over time due to the increase in restaurants and food stores over time (Economic Research Service - USDA, 2004; Lenard, 2012; National Association of Convenience Stores (NACS), 2011; National Restaurant Association, 2013; The Reinvestment Fund, 2011) and the increase in away-from-home eating (Duffey et al., 2007; Smith et al., 2014; Zick and Stevens, 2006). We quantified indirect pathways from fast food restaurants, sit-down restaurants, supermarkets, and convenience stores to BMI, through consumption of specific foods typically acquired at each type of food resource. We also included direct pathways between fast food restaurants, sit-down restaurants, supermarkets, and convenience stores to BMI to capture neighborhood effects that occur through unmeasured factors that are independent of diet.

2. Methods

2.1. Study population

The Coronary Artery Risk Development in Young Adults (CARDIA) study is a longitudinal cohort with detailed diet, clinical, physical activity, environmental, and sociodemographic data collected for 5114 white or black U.S. adults aged 18–30 years originally from 4 centers: Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA. Participants were recruited in 1985–86 (baseline Year 0) with approximately equal numbers by race, gender, education (high school or less versus more than high school), age (18–24 years versus 25–30 years) within each center, and followed over 25 years. We used data from baseline and 4 exams during 1992–93 (Year 7), 1995–96 (Year 10), 2000–01 (Year 15), and 2005–06 (Year 20). Retention was 81%, 79%, 74%, and 72% ($n=3549$) of the surviving cohort at these four exams, respectively.

2.2. Body mass index

At each examination, participants' weight (nearest 0.2 kg) and height (nearest 0.5 cm) were measured and BMI (kg/m^2) calculated. We used years 0, 7, and 20 to correspond with the primary diet measures described below.

2.3. Dietary assessment

An interviewer-administered CARDIA Diet History (McDonald et al., 1991) was used to assess diet at exam years 0, 7, and 20. The CARDIA diet history included a short questionnaire regarding general dietary practices followed by a comprehensive food frequency questionnaire about typical intake of foods using the previous month as a reference for recall. With a food-grouping system (University of Minnesota Nutrition Coordinating Center), we assigned foods to one of 13 food groups and 5 beverage groups [assessed as servings per day of constituent foods (Table 1)]. Since we did not have food purchase data, we selected foods and beverages we theorize are typically offered at fast food restaurants, sit-down restaurants, supermarkets, and convenience stores and that have been shown to be prospectively associated with weight change (Mozaffarian et al., 2011) and cardiometabolic outcomes (Duffey et al., 2012). We categorized dietary intakes (servings per day) and fast food restaurant visits (number per week) into low, medium or high by (1) year-specific tertiles or (2) as non-consumers (0 servings per day) versus upper and lower distributions of consumers (≥ 1 serving per day), with values defined in Table 2. Year-specific tertiles allowed for temporal changes in dietary behaviors.

We set reported dietary behaviors and BMI to missing when participants had extreme energy intakes (Sijtsma et al., 2012) [<800 or >8000 kcal/d for men ($n=73$ at year 0, $n=60$ at year 7, and $n=25$ at year 20); and <600 or >6000 kcal/d for women ($n=53$ at year 0, $n=34$ at year 7, and $n=29$ at year 20)] or when women were pregnant ($n=7$ at year 0, $n=62$ at year 7, and $n=6$ at year 20).

2.4. Neighborhood food environment

We used a geographical information system (GIS) of restaurants, food stores, and U.S. Census data that we geographically and temporally linked to CARDIA participants' home locations at years 0, 7, and 20. Study data were collected under written informed consent at each exam and protocols approved by Institutional Review Boards at each study center and the University of North Carolina at Chapel Hill.

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