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# Is a reduction in distance to nearest supermarket associated with BMI change among type 2 diabetes patients?



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## ABSTRACT

We examined whether residing within 2 miles of a new supermarket opening was longitudinally associated with a change in body mass index (BMI). We identified 12 new supermarkets that opened between 2009 and 2010 in 8 neighborhoods. Using the Kaiser Permanente Northern California Diabetes Registry, we identified members with type 2 diabetes residing continuously in any of these neighborhoods 12 months prior to the first supermarket opening until 10 months following the opening of the last supermarket. Exposure was defined as a reduction (yes/no) in travel distance to the nearest supermarket as a result of a new supermarket opening. First difference regression models were used to estimate the impact of reduced supermarket distance on BMI, adjusting for longitudinal changes in patient and neighborhood characteristics. Among patients in the exposed group, new supermarket openings reduced travel distance to the nearest supermarket by 0.7 miles on average. However, reduced distance to nearest supermarket was not associated with BMI changes. Overall, we found no evidence that reduced supermarket distance was associated with reduced levels of obesity for residents with type 2 diabetes.

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## 1. Introduction

Weight management is an important component of type 2 diabetes disease management but many patients struggle to follow self-care guidelines. In concert with other factors, the food retail options available in an individual's residential neighborhood may shape daily dietary choices and influence body weight and disease outcomes. In recognition of the influence of neighborhood factors on obesity, a growing number of localities and states are developing programs to increase the availability of healthful foods in low income areas ("California FreshWorks Fund," n.d.; City of New Orleans, 2013; Denver Food Access Task Force, 2011; Office of Sustainability, Department of Planning, 2010; The Reinvestment Fund, n.d.) These programs may provide financial incentives for supermarket operators and other food retailers to open or expand in areas with poor supermarket access.

In the epidemiologic literature on the health impacts of the

food retail environment, supermarkets are widely regarded as community health assets, because they tend to offer a greater variety of healthful food options (e.g. produce, whole wheat products, lean meats and low-fat dairy) at lower prices compared to smaller food stores (Chung and Myers, 1999; Horowitz et al., 2004). However, unhealthy foods such as fried snacks, sugary beverages, and calorie-dense convenience meals may also be more affordable and accessible in supermarkets.

Given the mixed nutritional quality of products at the average supermarket, the net health impact of greater supermarket proximity on body weight is unclear. While early cross-sectional studies found that greater supermarket proximity and density were associated with improved dietary quality and reduced obesity risk, (Morland et al., 2002, 2006; Rose and Richards, 2004; Laraia et al., 2004; Liu et al., 2007; Lopez, 2007; Moore et al., 2008) very few studies have assessed the health consequences of supermarket development on longitudinal outcomes and none assess longitudinal outcomes among those with chronic disease (Boone-Heinonen et al., 2011; Cummins et al., 2005; Elbel et al., 2015; Lee, 2012).

Surprisingly and in contrast to earlier research, preliminary

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findings from longitudinal studies do not support the premise that supermarket availability has a beneficial impact on health. A recent pilot evaluation of a supermarket intervention supported by [The Pennsylvania Fresh Food Financing](#) program found that the intervention store lifted community perceptions of healthful food availability but did not improve dietary quality or body mass index (BMI) ([Cummins et al., 2014](#)). That study compared dietary quality and BMI changes in the intervention community with outcome changes in a demographically comparable community that did not have supermarket development. The authors urged other researchers to conduct similar analyses in other locations. However, the logistical challenge of anticipating supermarket developments and collecting longitudinal health outcomes from area residents is a major barrier to study replication.

In contrast to the prospective approach detailed above, we conducted a secondary analysis of medical records in the Kaiser Permanente Northern California (KPNC) Diabetes Registry. This retrospective approach sidestepped the need to anticipate future supermarket developments and collect original survey responses. Instead, we exploited a dozen previous supermarket developments in eight Northern California neighborhoods as a quasi-experiment to estimate the influence of increasing supermarket proximity on change in BMI among neighborhood residents with diabetes.

## 2. Methods

We identified eight neighborhoods (defined below) in northern California in which 12 new supermarkets opened between 3/14/2009 and 9/15/2010. Seven of the eight neighborhoods had  $\geq 15\%$  of residents living below the federal poverty line, and three neighborhoods had  $\geq 20\%$  of residents living in poverty. Only one neighborhood, East Palo Alto, was located in a “food desert” as defined by USDA criteria ([Agricultural Marketing Service, USDA, n.d.](#)).

We defined periods before and after the period of supermarket openings (3/14/2009–9/15/2010) as baseline and follow-up, respectively: baseline was the twelve months preceding the first supermarket opening (03/14/2008–03/14/2009); follow-up was the 10 months after the last supermarket opening (9/16/10–7/15/11) ([Fig. 1](#)). The baseline and follow-up assessment period boundaries were constrained to a window of time in which no other large food retail changes (e.g., other supermarket developments, supermarket closures or supercenter grocery expansions) occurred within two miles of the neighborhood boundaries.

### 2.1. Neighborhood definition

Neighborhood geographic boundaries were defined by a two-mile radius around each supermarket along the street network ([Table 1](#)).<sup>1</sup> Overlapping buffer regions were merged into one neighborhood.

### 2.2. Store validation

We defined supermarkets as large grocery stores, supermarkets, wholesale stores, and supercenters with  $\geq \$2$  million dollars in annual sales,  $\geq 4$  cashiers,  $\geq 30$  varieties of fresh fruit,  $\geq 50$  varieties of fresh vegetables,  $\geq 10$  varieties of dairy,  $\geq 20$  varieties of meat or fish, and  $\geq 20$  varieties of frozen foods.

<sup>1</sup> In East Palo Alto, neighborhood boundaries were defined as the two network mile buffer around Mi Pueblo only, and the region around Trader Joe's was excluded due to its close proximity with a concurrent supermarket closure.

Between 05/09/2013 and 07/31/2013, the lead author visited each intervention supermarket to verify store address and confirm that in-store attributes met supermarket criteria. This “ground-truthing” also included verification that, within the study period, no other supermarket developments, closures, or supercenter expansions occurred within a two network mile radius of the intervention neighborhoods. Using 2008, 2009, 2010, and 2011 commercial lists obtained from InfoUSA Inc. (“[Infogroup.com](#),” n.d.) a proprietary information service offering commercial databases on business, we identified all supermarkets, supercenters, and large grocery stores within a two mile buffer outside the neighborhood boundaries. Using official store websites, news articles, [Yelp.com](#) (“[Yelp](#),” n.d.) and Google Streetview (“[Street View - Google Maps](#),” n.d.) we identified miscategorized listings and omissions from the InfoUSA list. The dates of store openings and, if applicable, closings for intervention stores and originally existing stores were obtained using the above resources and were cross-checked using off-sale license records from the California Department of Alcoholic Beverage Control (“[California ABC - License Query System](#),” n.d.) and inspection records from the local health department. We contacted supermarket staff to obtain missing information and conducted in-store audits to verify supermarket status of unrecognized store names.

### 2.3. Study sample

Kaiser Permanente Northern California (KPNC) is a large, integrated health care delivery system whose membership is broadly representative of the overall population in its service area in northern California, with the exception of the extreme tails of the income distribution ([Gordon and Kaplan, 1991](#)). The KPNC Diabetes Registry is a longitudinal cohort of KPNC members identified with diabetes using clinical records ([Moffet et al., 2009](#)). Individual-level administrative and clinical records for KPNC Diabetes Registry members were linked with geospatial measures by the member's address of residence from membership files.

The study sample is the subset of type 2 diabetes patients from the KPNC Registry who lived within one of the eight neighborhood boundaries from the first day of the baseline period (3/14/2008) to the last day of the follow-up period (7/15/2011). Members who relocated between start of baseline and end of follow-up ( $n=385$ ) were removed from the cohort. Members who were pregnant ( $n=9$ ) or who had bariatric surgery ( $n=10$ ), cancer ( $n=175$ ), or lower extremity amputations ( $n=24$ ) during or immediately preceding the study period were excluded from analyses due to the impact on changes in weight. Since sample restriction to patients with medical visits in the baseline and follow-up periods had the potential to selectively bias the sample, we imputed missing outcome measures for patients who did not have a medical visit in the baseline, follow-up or both periods. The final analytical sample was comprised of 3247 individuals in the main analysis, which incorporated subjects with imputed data, and 1908 individuals in a sensitivity analysis, which incorporated only subjects with complete outcome and covariate data.

### 2.4. Outcomes

Our main outcome measure was the patient-specific difference in average body mass index (BMI) between the baseline (03/14/2008–03/14/2009) and follow-up periods (9/16/10–7/15/11). Weight and height measurements were recorded by KPNC providers in each visit in the natural course of providing care. For each individual, average BMI values in baseline and follow-up were calculated as the averages of all patient BMI records available in the respective period from the KPNC electronic medical records. A quarter of the sample had missing values for BMI during baseline,

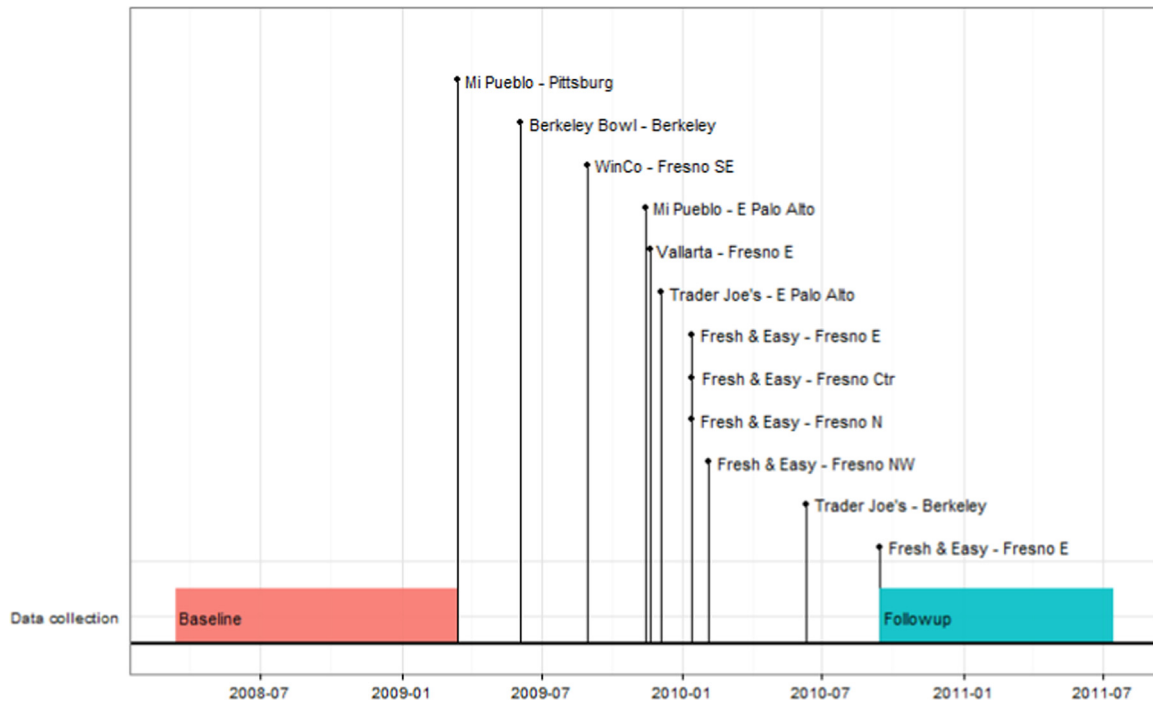


Fig. 1. Timeline of supermarket developments in study period.

**Table 1**  
Supermarket developments by neighborhood.

Neighborhood	N	N <sub>exposed</sub> (%)	Total new openings	Supermarket brands	Days to follow-up <sup>a</sup>	Poverty rate <sup>b</sup>
Berkeley	957	147 (15%)	2	Berkeley Bowl Trader Joe's	468	15.3%
Pittsburg	677	325 (48%)	1	Mi Pueblo	550	16.3%
East Palo Alto	319	288 (90%)	2	Mi Pueblo Trader Joe's	304	15.4%
Fresno Northwest	264	33 (12%)	1	Fresh & Easy	224	14.8%
Fresno North	234	38 (16%)	1	Fresh & Easy	245	8.7%
Fresno Southeast	197	35 (18%)	1	WinCo Foods	380	30.0%
Fresno East	461	143 (31%)	3	Vallarta Supermarket Fresh & Easy (2)	300	20.9%
Fresno Center	138	16 (12%)	1	Fresh & Easy	240	36.0%

<sup>a</sup> Number of days from earliest supermarket opening to first day of follow-up period

<sup>b</sup> Average census block group poverty rate among neighborhood participants. Census block group poverty rate is the percentage of households in the census block group with household income below the federal poverty level (American Community Survey, 2006–2010)

follow-up, or both. For these patients, missing values for BMI were imputed.

### 2.5. Exposure

The exposure of interest was a dichotomous indicator of a reduction in road network distance to the nearest supermarket due to a supermarket opening. The road network distance from each individual's residential census block centroid to the nearest supermarket was calculated using ArcGIS 10.1 (ArcGIS Desktop, 2012); the change in distance was calculated as the road network distance in the baseline period minus the distance in the follow-up period. Given that minor changes in supermarket distance may arise from random geocoding error, the exposed group was comprised of residents who experienced a reduction in distance to nearest supermarket of  $\geq 0.1$  mile and the unexposed group comprised of residents who experienced  $< 0.1$  mile reduction in distance.

### 2.6. Covariates

Annual clinical measures were extracted from medical and pharmacy records, and covariate measures were defined to represent change from baseline to follow-up. The Charlson comorbidity index is a validated measure of mortality risk based on diagnosis of any of 22 health conditions (Charlson et al., 1987; van Walraven et al., 2010). We also developed separate indicators for psychiatric medication use associated with weight gain (e.g. alprazolam) and psychiatric medication use associated with weight loss (e.g. bupropion HCL) based on pharmacy records. Specification of time-invariant individual-level covariates such as gender or race/ethnicity was unnecessary, because the statistical model adjusted for these factors.

We adjusted for a number of potential, time-varying neighborhood-level confounders and included indicators for each of the eight neighborhoods in the regression model. Specifically, we adjusted for changes in census block group population density using the difference in five-year aggregate measures from the American

Community Survey 2006–2010 to 2008–2012 (US Census Bureau, 2014). Additionally, we adjusted for concurrent changes in other retail density including fast food outlet count, produce store count, convenience store count, and physical activity resource kernel density within one network mile of each individual's residential block centroid. For the calendar years associated with the baseline (2008) and follow-up (2011) period, we identified retail locations based on NAICS and SIC industry code, keyword searches, and name recognition in the InfoUSA commercial database for each retail class.

### 3. Statistical analysis

A first difference regression model was used to model change in individual-level average BMI from baseline to follow-up as a function of exposure and change in covariates (Model 1) (Wooldridge, 2010). In a first difference model, the difference in outcome comparing time one to time two is modeled as a function of the differences in exposure and covariate values comparing time one to time two. With two time-periods, the first difference model specification is algebraically equivalent to the potentially more familiar fixed effects model with individual-level fixed effects.

A first difference model offers several advantages for estimating the health impact of non-randomized neighborhood-level interventions. First, covariates that do not change in value across time, such as race/ethnicity or sex, are assumed to have no impact on the direction or magnitude of outcome changes and can be omitted from the model. Additionally, the use of a first difference model combined with sample restriction to residents who remained at the same address over the study period ensured that individual-level changes in supermarket proximity over time were attributable to supermarket developments and not to residential mobility or other individual-level factors such as income or food preferences. In other words, we assumed that changes in a resident's individual-level attributes such as personal changes in food preference, have no causal impact on neighborhood supermarket openings or closures and therefore do not affect their change in supermarket proximity.

Model 1:

$$BMI_{it1} - BMI_{it0} = \beta_0 + I[(Dist_{it1} - Dist_{it0}) < -0.1] \beta_1 + (w_{it} - w_{it-1}) \beta_2 + (C_i) \beta_3 + (\epsilon_{it} - \epsilon_{it-1})$$

in which *i* subscripts the individual, *t* subscripts the time period (0 baseline, 1 follow-up).

$I[(Dist_{it1} - Dist_{it0}) < -0.1]$  is a binary indicator that travel distance to the nearest supermarket for subject *i* decreased by more than 0.1 mile from baseline to follow-up.

$w_{it}$  is a vector of time-varying covariates including Charlson comorbidity index, medication use associated with weight-gain, medication use associated with weight-loss, PA density, fast food outlet count, convenience store count, produce store count, and population density.

$C_i$  is a vector of dummy indicators for each neighborhood.

All statistical analyses were conducted in the R programming language (R Development Core Team, 2014). Missing data imputation for BMI and Charlson comorbidity index was conducted with predictive mean matching (PMM) using the Multiple Imputation by Chained Equations package (MICE) in R (Buuren and Groothuis-Oudshoorn, 2011). PMM is a method that imputes each participant's missing value by borrowing an exact value from a participant with similar covariates. We calculated confidence intervals empirically using 1000 bootstrap iterations to account for a potentially correlated error structure. In each bootstrap iteration, each missing outcome and covariate value was imputed with a single value and the model was fit anew on the post-imputation

data. To assess the impact of data imputation on model results, we also replicated the analysis using only patients with complete data on all measures (n=1908) in a sensitivity analysis.

### 4. Results

Individuals ranged from 23 to 101 years of age with an average age of 64 years (SD=14.7). The sample was ethnically diverse with 35% non-Hispanic white, 24% Black, 22% Hispanic, 10% Asian, and 9% other race (Table 2). The average BMI at baseline was 32.2 kg/m<sup>2</sup> and over half (56%) of patients were obese. Only 1% resided in a rural area.

As a result of the new supermarkets opening after the baseline period, a third of patients (32%) experienced a reduction in distance to a supermarket during the follow-up period. Prior to the opening of the new supermarkets, the average distance to the closest existing supermarket was 1.8 miles among the exposed and 0.8 miles among the unexposed group. Among patients in the exposed group, the new supermarkets reduced supermarket travel distance by 0.7 miles on average (median: 0.6, interquartile range: [0.3, 1.0]). By definition, patients in the unexposed group experienced no change in supermarket distance. The percentage of patients in the exposed group varied across the eight neighborhoods (Table 1). In East Palo Alto, the new supermarket developments decreased travel distance for 90% of patients, with an average of 1.3 mile reduction in distance to the nearest supermarket. In contrast, in Fresno Center, where the new supermarket opened 0.7 miles from an existing store, only 12% of patients experienced a reduction in travel distance to nearest store (0.3 mile average reduction).

A reduction in the distance to nearest supermarket was not associated with BMI changes in either unadjusted [0.15 (-0.07, 0.40)] or adjusted [0.17 (-0.07, 0.40)] models (Table 3). Neighborhood specific estimates were highly variable (-0.60 to 0.57

**Table 2**  
Clinical and neighborhood characteristics of study sample.

	Baseline Mean (SD)	Follow-up Mean (SD)	Difference Mean (SD)
<b>Individual-level variables</b>			
Race/ethnicity			
Non-Hispanic white	35.4%	N/A	N/A
Black	23.7%	N/A	N/A
Hispanic	22.1%	N/A	N/A
Asian	9.6%	N/A	N/A
Other race	9.1%	N/A	N/A
Female	48.0%	N/A	N/A
Age	64.4 (14.7)	N/A	N/A
BMI (kg/m <sup>2</sup> )	32.2 (7.2)	32.0 (7.4)	-0.2 (2.4)
Comorbidity Score	2.1 (1.5)	2.4 (1.6)	0.2 (1.2)
% on meds associated with weight gain	5.0%	5.9%	0.9%
% on meds associated with weight loss	6.4%	6.7%	0.3%
<b>Area-level variables<sup>a</sup></b>			
Produce store count (1 mi network radius)	0.4 (0.6)	0.4 (0.6)	0.0 (0.6)
Fast food count (1 mi network radius)	4.0 (3.3)	4.4 (3.6)	0.4 (1.2)
Convenience store count (1 mi network radius)	2.7 (2.1)	2.5 (2.2)	-0.2 (1.2)
Physical activity venue density (1 network radius)	2.0 (1.7)	2.2 (1.9)	0.1 (0.6)
Population density (pop/sq mi) (census block group)	9432 (5529)	9752 (5806)	320. (2145)
Federal poverty rate (census block group)	17.6% (1.9%)	19.7% (13.3%)	2.1% (9.6%)

<sup>a</sup> Area level variables were calculated around each individual residence.

**Table 3**  
Associations between reduction in supermarket travel distance and BMI change.

	N	Mean change in supermarket distance among exposed (mi)	ΔBMI	95% CI
Overall				
Unadjusted	3247	−0.7	0.15	[−0.07, 0.40]
Fully adjusted <sup>a</sup>	3247	−0.7	0.17	[−0.07, 0.40]
By specific neighborhood <sup>a</sup>				
Berkeley	957	−0.3	0.41	[−0.05, 0.91]
Pittsburg	677	−0.5	−0.22	[−0.60, 0.34]
East Palo Alto	319	−1.4	0.04	[−0.63, 0.94]
Fresno Northwest	264	−0.5	0.57	[−0.04, 1.38]
Fresno North	234	−0.4	0.23	[−0.62, 0.71]
Fresno Southeast	197	−0.5	0.11	[−1.26, 0.49]
Fresno East	461	−0.6	0.33	[−0.11, 0.88]
Fresno Center	138	−0.3	−0.60	[−2.46, 0.85]

<sup>a</sup> Adjusted for Charlson Comorbidity Index; medications associated with weight gain or loss; produce, fast food and convenience store count (within 1 mile); physical activity venue kernel density (within 1 mile); and population density.

BMI units). The data imputation process did not appear to bias study findings. In a sensitivity analysis on a subset of residents with complete measures ( $n=1908$ ), the adjusted association between BMI change and reduction in supermarket distance [(0.13 (−0.11, 0.39))] was comparable to the estimate obtained from the full sample.

## 5. Conclusions

In this longitudinal study, we estimated the effect of a reduction in the distance to the closest supermarket on BMI change among patients with type 2 diabetes. We took advantage of the opening of a dozen new supermarkets in eight northern California neighborhoods (March 2009–Sept 2010) and compared BMI changes over time for patients with reduction in supermarket distance versus patients in the same neighborhoods with no change in distance to the nearest supermarket. Contrary to our hypothesis, reduction in travel distance to closest supermarket was not associated with significant or substantive changes in BMI in a relatively short follow-up for this sample of type 2 diabetes patients.

Our study may, however, underestimate the impact of reduction in distance to closest supermarket on BMI in this population. First, the average reduction in supermarket distance, among patients who experienced any reduction, was small (only 0.7 miles.) While this change may alter food shopping patterns for patients who walk, bicycle, or take public transport to the supermarket, it may not be sufficient incentive to change shopping or consumption habits for patients who drive or are driven to the supermarket. While we did not survey the mode of transit for this study sample, a survey of 770 members from the Kaiser Permanente of Northern California Diabetes Registry in 2011–2012 found that over 90% of respondents reported commuting to the grocery store by car (Laraia and Hendrickson, 2014). Second, while we expected the greatest impacts of supermarket openings on patients with shortened distance to nearest supermarket; we anticipated spillover effects on patients in the comparison group as well, leaving only a modest difference in supermarket exposure between exposure and comparison groups. Lastly, our estimates may underestimate the impact of supermarket openings on BMI, because consumers need time to adjust food purchasing and consumption in response to new food retail opportunities. The time interval between store development and assessment may not have been sufficient to observe the full impact of reduced supermarket distance on BMI outcomes in this study.

Our study has other limitations in addition to the above. The

analysis sample represents an insured population of individuals with diagnosed type 2 diabetes. Since this sample represents patients who are actively engaged with the health care system, this sample may have shopping habits, dietary patterns, and metabolic outcomes that are not representative of the general population. Additionally, in most cases, both exposed and unexposed residents lived within one mile of an existing supermarket. Given these sample characteristics, the results of this study are not directly comparable to the aforementioned community health evaluation of the first full service supermarket in a food desert (Cummins et al., 2014). Moreover, this study had limited power to detect small effects in BMI change due to small sample sizes and limited variation in the exposure variable. Also, the time window of this analysis represents the worst recession of the US economy since the Great Depression and our findings may not generalize to different time periods. The supermarket openings in this period of economic recession may be intrinsically different from stores that open in non-recession years; store product mix, prices, marketing, and food purchasing patterns among consumers may have been particular to this time period. Additionally, we adjusted for localized changes in neighborhood attributes using census block group and one mile radius buffers as granular geographic units; nonetheless, omitted or inaccurately measured neighborhood-level changes could bias study findings in unexpected directions. Lastly, many factors influence shoppers' choice of food retail outlet aside from physical proximity. These other store qualities, such as price, quality, variety, cultural fit, cleanliness, safety, and customer service may affect patients' visits to and purchases at new supermarkets. While we verified that all 12 intervention stores stocked a wide variety of fresh produce, meats, dairy and frozen items, we did not conduct comprehensive in-store audits, nor did we verify whether individuals frequented intervention stores in the follow-up period. A low rate of adoption of the new stores would dilute any beneficial impact of increasing supermarket proximity on BMI outcomes.

With these limitations in mind, our study adds to the growing number of longitudinal analyses that failed to detect a beneficial effect of residential proximity to supermarkets on diet, weight, and associated health outcomes. Given that supermarkets offer a wide array of both healthful and unhealthful food options; it is time to re-evaluate common assumptions about the impact of their location on health. That said, our findings should not be interpreted as a broad dismissal of all programs that incentivize fresh food retail development in underserved communities. After all, we estimated an average effect of a relatively small reduction in supermarket distance across a wide variety of supermarket types, neighborhoods, and residents. The anticipated effects of

closer supermarket proximity on weight outcomes will likely depend on an interaction of resident, store and neighborhood characteristics.

Despite calls for wider adoption, quasi-experimental studies, which compare pre- and post-intervention outcomes for exposed and unexposed groups of subjects, are underused in neighborhood food retail environment research (Petticrew et al., 2005). The logistical challenge of accurately predicting future supermarket openings is a major barrier to study implementation. As other authors have discovered, collecting individual health outcome data in synchronization with supermarket development timelines is extremely difficult in practice (Cummins et al., 2014). In the present paper, we presented an alternative approach to estimating the causal impact of supermarket openings using retrospective data. Clinical and demographic measures from a health plan registry were matched with field-validated information on food retail changes and area-level measurements obtained from commercial and census-derived sources. We hope that our methods are helpful for future research and join the call for more rigorous longitudinal studies to help policymakers better understand the effects of food retail changes on both healthy and chronically ill community members.

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