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Healthy and Unhealthy Food Prices across Neighborhoods and Their Association with Neighborhood Socioeconomic Status and Proportion Black/Hispanic

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Abstract This paper evaluates variation in food prices within and between neighborhoods to improve our understanding of access to healthy foods in urbanized areas and potential economic incentives and barriers to consuming a higher-quality diet. Prices of a selection of healthier foods (dairy, fruit juice, and frozen vegetables) and unhealthy foods (soda, sweets, and salty snacks) were obtained from 1953 supermarkets across the USA during 2009–2012 and were linked to census block group socio-demographics. Analyses evaluated associations between neighborhood SES and proportion Black/Hispanic and the prices of healthier and unhealthy foods, and the relative price of healthier foods compared with unhealthy foods (healthy-to-unhealthy price ratio). Linear hierarchical regression models were used to explore geospatial variation and adjust for confounders. Overall, the price of healthier foods was nearly twice as high as the price of unhealthy foods ($0.590 vs $0.298 per serving; healthy-to-unhealthy price ratio of 1.99). This trend was consistent across all neighborhood characteristics. After adjusting for covariates, no association was found between food prices (healthy, unhealthy, or the healthy-to-unhealthy ratio) and neighborhood SES. Similarly, there was no association between the proportion Black/Hispanic and healthier food price, a very small positive association with unhealthy price, and a modest negative association with the healthy-to-unhealthy ratio. No major differences were seen in food prices across levels of neighborhood SES and proportion Black/Hispanic; however, the price of healthier food was twice as expensive as unhealthy food per serving on average.

Keywords Nutrition guidelines · Food price · Socioeconomic status · Race

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Introduction

The quality of the average diet in the USA is well below recommended dietary guidelines due to low fruit and vegetable consumption and high intake of added sugars, saturated fats, and sodium [1]. Dietary quality is even lower among African Americans, Hispanics, and those with low socio-economic status (SES) [2, 3].

Research has primarily studied physical access to healthier versus unhealthier foods by examining availability of supermarkets in a neighborhood. Areas without supermarkets are often classified as food deserts [4]. However, economic access—or affordability—may also play an important role in determining whether healthy foods are truly available to individuals in a neighborhood. If healthy food is physically available in the neighborhood, but many are unable to afford it, then access is still poor; this situation is referred to as a food mirage [5]. In addition, if unhealthy food is cheaper than healthy food, this may contribute to disparities in dietary quality since individuals of lower SES are more sensitive to prices and to food price in particular [6] due to a higher proportion of income spent on food [7]. Black and Hispanic populations often have lower SES compared with white populations; thus, price differentials could be contributing to their higher risk of obesity and diabetes [8].

The difference in price between unhealthy and healthy foods has been studied previously [9–13], finding that unhealthy foods—such as snacks [12] or high energy dense macronutrients (sugars, fats, and oils) [10]—were much less expensive compared with healthy foods such as fruits and vegetables. However, very little is known about small area price variations in healthy and unhealthy foods throughout the USA and whether prices vary according to neighborhood socio-demographics. Prior US work examining the relationship between food prices and area-level demographics have mostly been limited to within-city food store audits and examined availability and/or food quality within stores [14]. Findings suggest that in urban areas, store size and food quality differ by area-level demographics—with larger stores and higher-quality products less prevalent in lower-income areas [15–17]. Little work has been done that evaluated variation in food cost by area-level demographics after restricting to a particular size and type of store. The scant work that exists suggests that—after holding type of store constant—prices are not strongly patterned by area-level demographics [16, 18]. More large-scale work is needed on this topic.

The current study utilized a novel large dataset of prices of healthier and unhealthy foods in supermarkets in urbanized areas across the USA and assessed variation by neighborhood and price associations with neighborhood SES and proportion Black or Hispanic. Understanding how prices vary within and between neighborhoods will improve our understanding of access to healthy foods and potential economic incentives and barriers to consuming a higher-quality diet.

Methods

Price Data

Product pricing data were obtained from Information Resources Inc. (IRI), a market research group focused on consumer packaged goods sold in large chain supermarkets and superstores across the USA. Chain supermarkets represent 75% of all supermarket retailers, although not all supermarkets are included in the IRI dataset. The reasons for incomplete listing were as follows: (1) a few small city-level chains did not populate the IRI database and (2) some chains that were in the IRI database did not permit IRI to disclose the supermarket's address/block group and thus could not be used in the present study. Nevertheless, the database was very large and represented national, regional, and local supermarket chains. Examples of multi-regional and national megastores are Albertson's, A&P, Kmart, BJ's, Sam's Club, Walmart, etc., and regional and local supermarket chains are Food Emporium, Acme, Wegmans, SuperFresh, D'Agostino, etc. [19–21].

In total, data used in this study spanned January 2009 through December 2012 and came from 1953 stores located in 21 states (including Washington DC), 193 counties, and 1849 census block groups. Geographic regions were chosen to coincide with the addresses of participants in two longitudinal cohort studies (the Multi-Ethnic Study of Atherosclerosis and Jackson Heart Study) in order to use the price data in subsequent studies to examine the association between local food prices and health outcomes in those populations. Data elements were product category, item information (Universal Product Code [UPC] and package size), number of units sold, price of the item, store identifier, and store address. IRI's pricing database included 299 categories of packaged items—foods like cream/creamers, mustard/ketchup, spaghetti sauce, and non-foods such as household cleaners, diapers, tobacco.

The source data only included a small range of foods/beverages sold in supermarkets. Noteably, healthy foods such as fresh fruits and vegetables, lean meats, and a category for whole grains were not available in the IRI data. Instead, data were purchased for 9 available product categories to serve as proxies of unhealthy and healthier foods due to their ability to proxy the types of foods that are highly processed and generally considered less healthy vs the types of foods that are fresh and unprocessed and are generally considered healthier. For simplicity, we refer to the foods/beverages we selected as "unhealthy" and "healthy" foods but we note that these categories do not represent the full range of unhealthy and healthy products and the classifications are simplifications due to confines of the available data. We selected unhealthier foods from available items that were packaged, highly processed, and had a long shelf life: soda, chocolate candy, cookies, and salty snacks. We selected healthier foods from available items that were refrigerated, thus could roughly approximate costs of fresh fruit and vegetable spoilage and storage/distribution: refrigerated milk, yogurt, cottage cheese, frozen vegetables, and fresh orange juice (see Supplement Table 1 for details about the selected foods/beverages).

In order to purchase these data it was necessary to request data via UPC code. In total, 158 UPC codes for food items were selected that had the highest sales across multiple regions and stores. For this reason, all UPCs were top-selling branded items (n = 53 brands, e.g., Coca Cola, Hershey, Keebler, Lay's, Tropicana, Breakstone, Farmland, Dannon, Bird's Eye, etc.). A non-food product category, toilet paper, was also selected and used in statistical models in order to proxy the cost of doing business in a particular supermarket location (see more information below). A full list of all brands and example products for each of the food items included in this study can be found in Supplement Table 1.

Price Variables

Prices reflect the shelf price and included store-level promotions and retailer coupons, but did not include changes in price applied at the cash register, including taxes and manufacturer coupons. Volume equivalent prices were calculated as the price of an item divided by the number of ounces the item contained and multiplied by the typical serving size of each item (according to the FDA [22]) to create a price per serving size.

Prices per serving were averaged over the 4-year period (2009–2012) for each product category (e.g., milk). Temporal aggregation was done in order to maximize the presence of the same UPCs across regions/stores, increase sample size, and stabilize prices. There was little variability in inflation-adjusted prices between years during this time period [23]. The average price of all items in a product category was weighted according to volume sold (reported in IRI dataset) to create price per serving for each product category. Factor analyses used UPC-level price to identify product classes for healthier and unhealthy domains. This resulted in two healthier food classes: (1) milk, yogurt, and cottage cheese (AKA "dairy") and (2) fresh orange juice and frozen vegetables; and three unhealthy food classes: (1) soda, (2) cookies and chocolate candy (AKA "sweets"), and (3) chips, onion rings, and pretzels (AKA "salty snacks"). Product prices were then averaged within the healthier and unhealthy domains and weighted according to national consumption estimates. In general, results were similar when healthier and unhealthy domains were weighted equally across food classes, Supplement Table 2.

The average price of brand name toilet paper was calculated for each store in order to control for baseline costs specific to each store which may influence the price of food (e.g., rent, distribution, and employee wages) and may not be captured through other variables. Toilet paper is a good proxy for the basic cost of doing business for the following reasons: inhabits significant shelf space, non-perishable, unlikely to suffer from location specific supply shocks, and is unlikely to experience large shifts in demand (which could also lead price to reflect factors other than store level cost) [24].

Outcome Variables

Outcome variables were prices per serving at each of the supermarkets for each of the following product classes: dairy, fruit juice and frozen vegetables, soda, sweets, and salty snacks; as well as the overall price of our selection of healthier and unhealthy foods and the relative price of healthier foods compared with unhealthy foods (AKA healthy-to-unhealthy price ratio). The relative price was operationalized as the ratio of the average price per serving of healthier food divided by the average price per serving of unhealthy food. A ratio >1.0 indicates that the average price of a single serving of healthy food is more expensive than the price of a serving of unhealthy food (i.e., 1.92 means the price of a serving of healthy food is 92% or 1.92 times more expensive than the price per serving of unhealthy food on average). A ratio <1.0 indicates that a serving of unhealthy food is more expensive than healthy food.

Census Variables

Each store was assigned to the population-weighted centroid of their block group. Block groups within 1 mile of each store were selected and census data were averaged for those block groups, in order to characterize the census composition around the stores. All block groups intersecting the 1-mile buffer were included as part of the store's neighborhood, and census data were weighted according to the population of each included block group. The 1-mile buffer was chosen to expand the supermarket's neighborhood beyond the block group in which it was located, which may be an industrial area with a low population and not representative of the surrounding neighborhood. A 1-mile buffer has been referred to as a relevant consumer market area for a supermarket [25]. A supermarket's neighborhood included a median of 13 block groups and 95% of stores had at least 4 block groups within the 1 mile radius surrounding its location. A sensitivity analysis used a 2-mile buffer and results were similar (Supplement Table 3).

Census data were obtained from the 2007–2011 American Community Survey (ACS) 5-year summary file. Neighborhood *SES index* was created using six variables from the ACS representing wealth and income, housing value, education, and managerial or professional occupations and was operationalized as a single continuous measure as described by Diez-Roux et al. [26] (see Table 2 footnote). Neighborhood proportion of Black or non-white Hispanic (AKA "Black/Hispanic") and neighborhood SES were converted into percentiles and units represent 20-percentile increments. To control for potential differences in age distribution and population across block groups, the proportion of individuals aged 20 to 39 years (standardized as a z-score) and the population density (individuals per square kilometer) were included as covariates in multivariable models.

Geographic Variables

Geographic region (Northeast, Midwest, South, and West) and urbanicity of each store location were included as covariates in the regression analysis. Both were included to control for differences in infrastructure and other aspects of the built environment unique to regions or to cities versus rural areas which could affect the shelf price of foods. Urbanicity was based on county population size and was operationalized as a categorical variable with three levels: large metropolitan area of 1+ million residents, small metropolitan area of less than 1 million residents, and micropolitan (centered on an urban area with population 10,000 to 49,999) and non-core areas (all other areas smaller than micropolitan) [27].

Supermarket Density

Supermarket density data were obtained from the National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP) of the CDC. The NCCDPHP compiled the number of chain and non-chain supermarkets within each census tract or within 0.5 miles of the tract boundary [28]. Further information regarding the methodology used to identify and categorize food retailers can be found in the NCCDPHP publication by Grimm et al. [28] Supermarket density was included as a covariate to control for potential differences in market competition that may affect product prices [29].

Statistical Analysis

Bivariate associations between socio-demographics (neighborhood SES, Black/Hispanic, region, and urban class) and food/beverage prices were analyzed using unadjusted normal linear models. SES and Black/Hispanic were treated as continuous variables (after verifying approximately linear relationships with price), and region and urbanicity were treated as categorical variables.

Food store (supermarket) was the primary unit of analyses. Hierarchical models nesting stores within counties and states were used to account for the spatial dependence of prices between stores proximal to each other. The first models aimed to describe the effect of geography on food prices. The models controlled for geographic region and urbanicity as geographic fixed effects along with store-level toilet paper price to control for baseline costs. Random intercepts for state and county allowed mean price to vary across space and accounted for the correlation between prices within a given geographic area. The variance of price that was explained at the state and county level was calculated, with the remaining error considered variation at the store level.

Lastly, multivariable hierarchical models adjusting for additional census variables and supermarket density were analyzed. Black/Hispanic and SES effects were first modeled separately with no covariates. The models then controlled for age, region, urbanicity, population density, supermarket density, toilet paper price, and Black/Hispanic (in the SES model) and SES (in the Black/Hispanic model). The effects of 20 percentile increases in Black/Hispanic and SES were reported along with 95% confidence intervals and *p* values.

All statistical analysis was performed in SAS v9.3 (Cary, NC). Spatial methods linking stores to their neighborhoods were performed using ArcGIS v10.0.

Results

Descriptive Results

Most of the 1953 stores were located in large metropolitan areas (82.2%, Table 1) and in the south (51.7%). The price of healthier foods was nearly twice as high as the price of unhealthy foods ($0.590 vs $0.298 per serving [PS]), a trend that was consistent across all measured neighborhood characteristics and resulted in a healthy-to-unhealthy price ratio of 1.99 (Table 2).

For the healthier food domain, there was a slight decrease in the price of healthier foods, averaged over product classes, as neighborhood SES decreased ($0.611 vs $0.581 PS in highest to lowest SES quintile). However, within the healthier food domain, the product category gradient differed: fruit juice and frozen vegetables *decreased* in price as neighborhood SES decreased ($0.526 vs $0.460 PS) while dairy *increased* in price ($0.747 vs $0.788 PS) (Supplement Table 4). For the unhealthy food domain, prices were nearly identical between low and high SES quintiles ($0.299 vs $0.306 PS), and there were no noteworthy variations within unhealthy food domain product categories. Thus, prices of healthier food drove variation in the healthy-to-unhealthy price ratio by neighborhood SES. The ratio was slightly weaker in lower SES areas: 2.01 vs 1.95 PS in the highest vs lowest quintiles, respectively (Table 2). The association between neighborhood Black/Hispanic and food prices followed a similar yet inverted pattern as the SES: areas with a higher proportion Black/Hispanic had higher dairy prices, lower fruit juice and frozen vegetable prices, and little difference in the price of unhealthy foods. Similarly, the healthy-to-unhealthy price ratio mirrored what was found for SES (2.00 vs 1.97 PS for neighborhoods with the lowest vs highest proportion Black/Hispanic).

Table 1 Neighborhood demographics and food prices for the study sample.

	Mean/*N*	SD/%
Number of stores	1953	
Neighborhood demographics		
Proportion Black/Hispanic (mean, SD)	0.37	0.25
Urban classification		
Large metro (pop. ≥1 million)	1606	82.2
Small metro (pop. <1 million)	296	15.2
Rural (pop <50k)	51	2.6
Region		
Northeast	207	10.6
Midwest	173	8.9
South	1009	51.7
West	564	28.9
Age, proportions (mean, SD)		
18 years or younger	0.24	0.05
18–34 years	0.24	0.08
35–64 years	0.40	0.05
65 or older	0.12	0.05
Supermarket density (mean, SD)[a]	3.34	2.25
Population density (mean, SD)	1930	3091
Food prices per serving (mean, SD)		
Healthy foods		
Frozen vegetables	$0.472	$0.073
Orange juice (OJ)	$0.506	$0.037
Fruits and vegetables (OJ and frozen vegetables)	$0.489	$0.051
Dairy	$0.760	$0.100
Healthy food composite	*$0.590*	*$0.056*
Unhealthy foods		
Soda	$0.217	$0.029
Chocolate	$0.535	$0.050
Cookies	$0.214	$0.035
Sweets (chocolate and cookies)	$0.375	$0.037
Salty snacks	$0.290	$0.014
Unhealthy food composite	*$0.298*	*$0.024*
Healthy vs unhealthy food price		
Healthy-to-unhealthy ratio	1.990	0.190

[a] Number of supermarkets within the supermarket census tract or within 1.5 mile of the tract

Table 2 Price of foods by area-level demographic characteristics around each store.

	Number of stores	Healthy food price per serving[a]		Unhealthy food price per serving[a]		Healthy-to-unhealthy price per serving[a]	
		Mean	SD	Mean	SD	Mean	SD
Overall	1953	$0.590	$0.056	$0.298	$0.024	$1.990	$0.190
Neighborhood SES quintile[b]							
Lowest quintile (least advantaged)	391	$0.581	$0.047	$0.299	$0.019	1.950	0.175
Second quintile	391	$0.581	$0.048	$0.295	$0.020	1.974	0.177
Middle quintile	390	$0.589	$0.053	$0.295	$0.017	2.003	0.196
Fourth quintile	391	$0.590	$0.057	$0.294	$0.016	2.014	0.204
Highest quintile (most advantaged)	390	$0.611	$0.068	$0.306	$0.039	2.010	0.190
Proportion Black/Hispanic quintile							
Lowest quint. (0.8 to 14.0% Black/Hispanic)	390	$0.592	$0.058	$0.297	$0.033	$2.002	$0.182
Second quint. (14.0 to 24.0%)	392	$0.591	$0.058	$0.298	$0.026	$1.990	$0.187
Middle quint. (24.0 to 37.8%)	390	$0.593	$0.060	$0.297	$0.022	$2.004	$0.203
Fourth quint. (37.9 to 58.4%)	391	$0.587	$0.054	$0.297	$0.019	$1.981	$0.194
Highest quint. (58.5 to 98.8%)	390	$0.588	$0.050	$0.299	$0.018	$1.974	$0.184
Urban classification							
Large metro (pop. ≥1 million)	1606	$0.596	$0.058	$0.298	$0.026	$2.007	$0.192
Small metro (pop. <1 million)	296	$0.568	$0.042	$0.298	$0.015	$1.912	$0.163
Rural (pop <50k)	51	$0.553	$0.023	$0.291	$0.015	$1.904	$0.139
Region							
Northeast	207	$0.594	$0.074	$0.314	$0.052	$1.912	$0.179
Midwest	173	$0.599	$0.026	$0.279	$0.014	$2.155	$0.106
South	1009	$0.555	$0.024	$0.295	$0.018	$1.888	$0.138
West	564	$0.650	$0.043	$0.302	$0.013	$2.152	$0.143

[a] Composite healthy and unhealthy food prices were weighted based on national consumption averages of each food category

[b] Neighborhood SES was derived from log of the median household income; log of the median value of housing units; the percentage of households receiving interest, dividend, or net rental income; the percentage of adults 25 years of age or older who had completed high school; the percentage of adults 25 years of age or older who had completed college; and the percentage of employed persons 16 years of age or older in executive, managerial, or professional specialty occupations.

Model Results

To understand the contribution of area-level characteristics to price differences, a variance decomposition analysis was performed, first including only the random effects of state and county ("empty model"), and then adjusted for fixed effects of region, urbanicity, and price of toilet paper at the store. In the empty model, state-county level attributes accounted for approximately 70 and 50% of unexplained variability in prices for unhealthy and healthier food/beverage prices, respectively (Table 3). After fixed effect adjustment for region and urbanicity, unexplained price variation at the state-county level was slightly lower for unhealthy prices (dropped from 67 to 61%) and a lot lower for healthy price (dropped from 48 to 26%). The fixed effects primarily accounted for unexplained variability at the state-level (rather than the county-level). These results conform to prior work that found fairly low spatial variability in unhealthy prices but moderate variability in healthy prices [23]. Variability in the healthy-to-unhealthy price ratio was similar to the unhealthy food price variability after adjusting for the fixed effects. Further adjustment for area-level SES and Black/Hispanic had minimal effect on the decomposition results (data not shown).

Table 4 shows the estimated associations of neighborhood SES and proportion Black/Hispanic with each of the price outcomes, including composite healthy and unhealthy food prices and their ratio. After adjustment,

Table 3 Food price variance decomposition by geographic area before and after adjusting for region, urbanicity, and toilet paper price

	Healthy-to-unhealthy price ratio variance (SE)	Healthy food price variance (SE)	Unhealthy food price variance (SE)
Empty model			
Between states	0.0146 (0.0054)	0.0006 (0.0002)	0.0002 (0.0001)
Between counties (in states)	0.0047 (0.0008)	0.0003 (0.0001)	0.0002 (0.0000)
Within counties	0.0118 (0.0004)	0.0010 (0.0000)	0.0002 (0.0000)
ICC (state level)	47.0%	31.5%	38.1%
ICC (county level)	15.1%	16.8%	28.7%
Residual	37.9%	51.6%	33.2%
Control for region, urbanicity, and toilet paper price			
Between states	0.01 (0.0042)	0.0001 (0.0001)	0.0002 (0.0001)
Between counties (in states)	0.0048 (0.0008)	0.0002 (0.0000)	0.0001 (0.0000)
Within counties	0.0118 (0.0004)	0.0008 (0.0000)	0.0001 (0.0000)
ICC (state level)	37.6%	9.7%	43.8%
ICC (county level)	18.1%	15.9%	17.2%
Residual	44.3%	74.4%	39.0%

CI confidence interval, *ICC* intraclass correlation, the proportion of variation in price that is accounted for by differences at the state and county levels, *SE* standard error

neighborhood Black/Hispanic was positively associated with composite index for unhealthy food price (positive associations with price of sweets and salty snacks, but no association with soda) but was not associated with healthy food prices (no associations with fruits/vegetables or dairy). This resulted in a small consistently negative association with the healthy-to-unhealthy price ratio, indicating that the price differential was slightly attenuated with increases in proportion Black/Hispanic (for every 20 percentile increase in proportion of Black/Hispanic, the PS price of healthy food relative to unhealthy food was 1.3% lower [95% CI: −0.7 to −1.9%]). Proportion Black/Hispanic and neighborhood SES were positively correlated (Spearman rank correlation coefficient of −0.69, $p < 0.001$), thus competing for variance in food price. Nevertheless, after adjustment for age, region/urbanicity, population density, toilet paper price, and supermarket density, the estimated associations between proportion Black/Hispanic and food price changed very little after adjustment for neighborhood SES.

In general, model results for neighborhood SES were similar to the food price gradient observed in descriptive results. After adjustment, neighborhood SES was not consistently associated with composite food score, and associations were null after adjustment for Black/Hispanic area-level composition. Neighborhood SES was not associated with the composite index for healthy food prices (due to opposing SES gradients for fruit juice/frozen vegetables and dairy), was inconsistently associated with the composite index for unhealthy food price (no association with soda price, a small positive association with the price of sweets, and a small negative association with salty snacks), and a slight positive association with healthy-to-unhealthy price ratio became null after adjustment for Black/Hispanic area-level composition.

Results from sensitivity analysis using a 2-mile buffer were consistent and similar in magnitude to primary results using a 1-mile buffer (Supplement Table 3).

Discussion

Across all regions and neighborhoods, the average price per serving of healthy food was nearly twice as high as unhealthy food. There were no strong associations between neighborhood SES and neighborhood Black/Hispanic and composite indices for price of healthy foods or unhealthy foods. The only notable associations were within product categories for the healthy food

Table 4 Mean differences in price per 20% increase in neighborhood socioeconomic index (SES) and neighborhood proportion Black/Hispanic. Estimates were derived from hierarchical model estimates where stores were nested within counties and states, $N = 1953$ stores.

Price outcome variables		*Estimates for neighborhood SES*				*Estimates for neighborhood proportion Black/Hispanic*			
	Model	Estimate[a]	95% CI			Estimate[a]	95% CI		
			Lower	Upper	*P* value		Lower	Upper	*P* value
Healthy food price	Unadjusted[b]	0.00452	0.0034	0.0056	<0.0001	−0.00319	−0.0043	−0.0020	<0.0001
	Partially adjusted[c]	0.00085	−0.00027	0.00198	0.1370	−0.00059	−0.00171	0.00053	0.3019
	Fully adjusted[d]	0.00090	−0.0007	0.0025	0.2836	0.00007	−0.0016	0.0017	0.9377
Fruit juice and frozen vegetables	Unadjusted[b]	0.01386	0.0126	0.0151	<0.0001	−0.01069	−0.0120	−0.0094	<0.0001
	Fully adjusted[d]	0.01096	0.0091	0.0128	<0.0001	−0.00089	−0.0028	0.0010	0.3484
Dairy	Unadjusted[b]	−0.01323	−0.0153	−0.0112	<0.0001	0.01105	0.0089	0.0132	<0.0001
	Fully adjusted[d]	−0.01836	−0.0215	−0.0152	<0.0001	0.00223	−0.0009	0.0054	0.1687
Unhealthy food price	Unadjusted[b]	0.00057	0.0001	0.0011	0.0234	0.00058	0.0001	0.0011	0.0224
	Partially adjusted[c]	−0.00102	−0.00148	−0.00056	<0.0001	0.00171	0.00126	0.00217	<0.0001
	Fully adjusted[d]	0.00055	−0.0001	0.0012	0.1110	0.00212	0.0014	0.0028	<0.0001
Soda	Unadjusted[b]	0.00051	−0.0001	0.0011	0.0937	0.00022	−0.0004	0.0008	0.4764
	Fully adjusted[d]	0.00065	−0.0003	0.0016	0.1682	0.00077	−0.0002	0.0017	0.1063
Sweets	Unadjusted[b]	0.00267	0.0018	0.0035	<0.0001	−0.00053	−0.0014	0.0003	0.2244
	Fully adjusted[d]	0.00153	0.0005	0.0026	0.0054	0.00360	0.0025	0.0047	<0.0001
Salty snacks	Unadjusted[b]	−0.00216	−0.0025	−0.0018	<0.0001	0.00220	0.0018	0.0026	<0.0001
	Fully adjusted[d]	−0.00125	−0.0018	−0.0007	<0.0001	0.00122	0.0007	0.0018	<0.0001
Healthy-to-unhealthy price ratio	Unadjusted[b]	0.01146	0.0076	0.0153	<0.0001	−0.01486	−0.0187	−0.0110	<0.0001
	Partially adjusted[c]	0.00980	0.00558	0.01402	<0.0001	−0.01302	−0.01723	−0.00880	<0.0001
	Fully adjusted[d]	0.00037	−0.0059	0.0066	0.9088	−0.01274	−0.0190	−0.0065	<0.0001

[a] Per 20 percentile change in neighborhood SES or Black/Hispanic

[b] Unadjusted models did not include covariates but were adjusted for county and state via model nesting

[c] Partially adjusted includes covariates: age, region, urbanicity, population density, supermarket density, toilet paper price

[d] Fully adjusted includes covariates: age, region, urbanicity, population density, supermarket density, toilet paper price, and either race (in the SES models) or neighborhood SES (in the race models)

domain. For example, the price of dairy appeared to be higher in neighborhoods of lower SES and with higher proportion of Black/Hispanic, whereas the price of fruit juice and frozen vegetables was lower in those same neighborhoods. There was little variation in price of unhealthy food across neighborhood demographics regardless of the product examined. The healthy-to-unhealthy price ratio was slightly lower as the proportion of Black/Hispanic increased (even after adjusting for neighborhood SES and other covariates); there was no evidence of an adjusted association between the price ratio with neighborhood SES. Dairy was more expensive in neighborhoods of lower SES and with a larger proportion of Black and Hispanic individuals while fruit juice and frozen vegetables were less expensive in those same neighborhoods. Typically, dairy prices are more expensive in urban areas due to federal and state pricing regulations which dictate that prices increase in counties the closer they are to major consumption areas (i.e., heavily populated areas) [30]. In our study, Black and Hispanic individuals are mostly concentrated in urban neighborhoods which may be the reason we see higher dairy prices in areas with higher concentration of Black/Hispanic, even after controlling for region and urbanicity. Conversely, there are no such regulations for the unhealthy foods we studied, and in general, prices of those foods were quite stable across stores in our sample, resulting in no detected association between unhealthy foods with area characteristics (either SES or proportion Black/Hispanic).

Large absolute differences in price between healthy and unhealthy foods are consistent with previous work that found prices of soft drinks much lower than fluid milk [23], and sugars, fats, and oils much lower than fruits, vegetables, meat, and poultry in a second study [10], and a third study that reported higher diet costs were associated with a higher-quality diet as measured by the Healthy Eating Index-2005 [31]. These differences are likely due to the increased costs of refrigeration, farming, and transportation for perishables versus lower such costs for long shelf-life packaged/processed foods. The combination of lower price and increased availability of packaged/processed foods may be having profound effects on food purchases and result in less-than-optimal diet quality across a broad spectrum of the population [32]. The large price divide between healthier and unhealthy foods is concerning; dietary guidelines emphasize the consumption of fruits, vegetables, and low-fat dairy while limiting intake of sugar, saturated fats, and sodium [1]. If healthy foods cost twice the amount per serving as unhealthy foods, meeting these dietary guidelines will be difficult for many people, especially those of lower SES. Additionally, recent work has reported higher prevalence of soda/fast-food advertising in neighborhoods with higher proportion Black/Hispanic and lower income [33]. The confluence of high availability, exposure to advertising, and lower price may contribute to high consumption of unhealthy foods in these populations [34–36].

Economists note that the demand for a food product is influenced by its price and the price of potential substitutes [37]. For every 10% increase in the price of fruit juice and frozen vegetables, the quantity demanded of sugars and sweets rises of upwards to 1%, and the quantity demanded of snacks and fats and oils increases up to 0.6% [38]. Because of these cross product elasticities, it is possible that the unhealthy and healthy food price differentials that we observed may be responsible for a potential 10% increase in the consumption of unhealthy foods high in sugar and fat. Given the large discrepancy in price, it would take a radically large, and unlikely, tax on junk food (or similar intervention) to make the two prices equal.

We used a UPC level dataset and were only able to purchase a small number of items to represent healthy and unhealthy domains. This is similar to prior research that has heavily relied on index food and beverage products. For example, researchers have used index items from the Council for Community and Economic Research (C2ER; formerly the American Chamber of Commerce Researchers Association), a price dataset for 34 food/beverages sold in US metropolitan areas (pizza, steak, ground beef, bacon, etc.) [39–41], and average national prices for more than 3000 foods from the Center for Nutrition Policy and Promotion have been used to study the relationship between food prices and nutritional value [10, 42]. The primary problem with databases used in prior work is that they lack geographic specificity thus cannot be used to link prices to neighborhood socio-demographics. A strength of our study was the ability to link store locations to their immediate surrounding neighborhoods. While prior work has examined the prices of different food types, the use of metropolitan area level information did not allow examination of whether those prices vary across different neighborhoods within those metropolitan areas. This work provides important insight into the variation of healthier and unhealthy food prices and their relationship with race and SES within neighborhoods across the USA.

Results suggest that healthier and unhealthy food prices vary only slightly by neighborhood sociodemographics, and in the case of neighborhood SES, the direction was inversed from our hypothesis. These findings offer some good news: while healthier foods were twice the price of unhealthier foods, we found no evidence that within chain supermarket venues, healthier foods were more expensive and unhealthy foods cheaper in lower SES and Black/Hispanic areas. However, our findings are generalizable only to supermarkets. Prior studies have noted that areas with lower SES and higher proportion minority are more likely to have smaller grocery stores and fewer large supermarkets and thus food costs are sometimes higher in those areas due to lower access to large stores [14]. Thus, price differentials may exist between lower and higher SES communities due to area-level differences in types of food stores. In addition, our study did not consider food quality differences or differences in product placement—for equivalent foods/beverages between lower and higher SES neighborhoods. Even if prices do not systematically differ for equivalent store types and foods, food quality (freshness) [15] and/or product placement [43] may differ by neighborhood SES which could impact purchasing behaviors. Nevertheless, it is a strength of this study that we focused on supermarkets as they are the major venue for all US retail food sales (63% of all retail food sales from 2009 to 2012 [44]) and a very rich supermarket pricing dataset was available. In sum, major advantages of the dataset used in the current study are as follows: (1) food/beverage prices were geographically disaggregated to store locations/neighborhoods and (2) the dataset offered good generalizability to large chain supermarkets in urbanized areas across multiple areas of the USA for multiple years (rather than prices for a single city as some others have done [18, 45]).

This study relied on price per serving as the primary unit of analysis. Other measures of price that have been used in previous research include the price per calorie [9, 35] and price of edible food weight (e.g., price per gram or ounce) [46]. Using price per calorie has been criticized [12, 47] due to a statistical artifact the measurement creates. And while price per gram or ounce is useful when the foods being compared have comparable forms and serving sizes, the comparison becomes more difficult to interpret when the types of foods (e.g., soft drinks versus produce) and/or the serving sizes differ substantially. Thus, we chose the unit of analysis that could be compared across all product types, and which may be most meaningful to consumers: price per serving, which has been used previously in similar research [12, 48].

Ideally, we would have included fresh fruits and vegetables but they were unavailable in the source dataset. Few studies have assessed differences in prices of fresh and frozen vegetables in supermarkets in diverse regions of the USA throughout the year. The few studies that exist note that price of fresh refrigerated orange juice is highly correlated with the price of fresh oranges [49], and the price of frozen vegetables is largely similar to those that are fresh, though the magnitude of the correlation varies by type of vegetable and local growing season/local availability [48]. We chose perishable foods to be representative of healthier foods in order to reflect the price of fresh produce and dairy whose costs are largely due to transport and perishability. However, not all healthy foods are perishable and thus prices of perishable foods may not be representative of all healthy foods. It is unclear how the results may have differed had the entire universe of healthy and unhealthy foods been included. Nevertheless, the selected products we included are not unreasonable proxies for healthier and unhealthy foods, represent some of the best available data reported in the literature, and serve to highlight the large difference in price between these types of foods/beverages. Only branded products were included (see "Methods" for the rationale). Using brands ensured comparability of products with and across regions. Brands dominate market share for most of the unhealthy products (e.g., soda [50], salty snacks [51], chocolate candy [52]) and some (orange juice [53]) but not all (dairy [54] and frozen vegetables [55]) of the healthier products. Furthermore, our study lacked sociodemographics of consumers purchasing food at each store; thus, the findings of this study are limited to neighborhood level associations rather than associations between consumers' race, SES, and food prices at stores where they shop.

Conclusions

This study is one of the first to examine the relationship between healthy and unhealthy foods and their relationship within and between neighborhoods in regions across the USA. While no major differences were seen in supermarket food prices across levels of neighborhood SES and Black/Hispanic, overall, the price of healthy food was twice as expensive as unhealthy food. Such large differences in the affordability of healthy food compared with unhealthy substitutes may be resulting in less than optimal diet across all population groups and in particular individuals of lower SES who are more sensitive to price differences [6]. Further research is needed to determine the extent to which price influences overall diet quality and potential downstream health effects such as obesity, diabetes, and cardiovascular disease.

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Compliance with Ethical Standards

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