



# Change in Neighborhood Socioeconomic Status and Adherence to the Cancer Prevention Lifestyle Guidelines in Hispanic/Latino Adults: Results from the HCHS/SOL Study

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## ABSTRACT

Neighborhood conditions are dynamic; the association of changing neighborhood socioeconomic factors with cancer preventive behaviors remains unclear. We examined associations of neighborhood socioeconomic deprivation, gentrification, and change in income inequality with adherence to the American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention in The Hispanic Community Health Study/Study of Latinos (HCHS/SOL). The HCHS/SOL enrolled 16,415 adults, ages 18–74 years, at baseline (2008–2011), from communities in the Bronx, NY, Chicago, IL, Miami, FL, and San Diego, CA. Geocoded baseline addresses were linked to the 2000 decennial Census and 5-year American Community Survey (2005–2009 and 2012–2016) tracts to operationalize neighborhood deprivation index (NDI), gentrification, and income inequality. Complex survey multinomial logistic regression models estimated the relative risk ratio (RRR) with overall guideline adherence level (low, moderate, high) and by components—diet, physical activity, body mass index (BMI), and alcohol intake. Overall, 14%, 60%, and 26% of the population had low, moderate, and high ACS guideline adherence, respectively. NDI was negatively associated with risk of high (vs. low) guideline

adherence [RRR = 0.87, 95% confidence interval (CI) = 0.78–0.98], although attenuated after controlling for individual socioeconomic status (SES; RRR = 0.89, 95% CI = 0.80–1.00), and associated with lower adherence to BMI recommendations (low vs. moderate RRR = 0.90, 95% CI = 0.84–0.97; high RRR = 0.86, 95% CI = 0.77–0.97). Gentrification was associated with higher likelihood of meeting the dietary recommendations (low vs. moderate RRR = 1.04, 95% CI = 1.01–1.07), but not with overall adherence or individual components. Change in income inequality was not associated with outcomes. Neighborhood deprivation may be negatively associated with ACS guideline adherence among Hispanic/Latino adults.

**Significance:** This study provides new evidence on the link between neighborhood gentrification, changing income inequality and adoption and maintenance of cancer preventive behaviors in an understudied population in cancer research. We observed that while neighborhood deprivation may deter from healthy lifestyle behaviors, positive changes in neighborhood SES via the process of gentrification, may not influence lifestyle guideline adherence among Hispanic/Latino adults.

## Introduction

Adherence to the American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention (1, 2), has been linked to lower obesity-

related cancer risk (3–5). Obesity, a disease with a high burden among U.S. Hispanic/Latino adults (6), can be modified through healthful lifestyles to decrease obesity-related cancer risk (4, 5) and mortality (5) among Hispanic/Latino adults. Yet, adherence to these recommendations remains low

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**doi:** 10.1158/2767-9764.CRC-23-0187

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among Hispanic/Latino adults (3–5). The high prevalence of obesity and adverse lifestyle behaviors in Hispanic/Latino individuals may be linked to sociocultural, economic, environmental, and structural factors that predispose individuals to poor health behaviors and risk of obesity-related cancers (7, 8).

The U.S. legacy of overt (e.g., slavery and segregation) and covert (e.g., residential, commercial, and educational redlining) racism led to the concentration of racially and ethnically minoritized communities in under-resourced neighborhoods (9, 10), thereby concentrating poverty (11, 12) and unequal exposures to environmental hazards (13, 14). For example, neighborhoods with high Hispanic/Latino segregation often have high levels of deprivation (12, 15) and are known to predispose residents to higher risk of obesity (16, 17) through fewer resources and opportunities to engage in healthy lifestyles and as such, may be less able to meet the guidelines for cancer prevention (18–20). These neighborhoods often lack infrastructure for physical and recreational activities, have low walkability, are unsafe/have more crime (21–25), and lack access to healthy and high-quality foods (24, 26) including fresh produce (27). Neighborhoods with high concentrations of low socioeconomic and racially and ethnically minoritized groups are more likely to have adverse and low quality food environments (28, 29), spaces with reduced walkability (24), limited recreational resources (25, 30), increased risk of obesity (31), and poor perceived health (32). In turn, these environments are known risk factors for poor diet quality (32–35) and physical inactivity (36). We previously linked residential areas with lower economic and racial privilege [i.e., racialized economic segregation (37)] and neighborhoods with high Hispanic/Latino segregation to low adherence to the overall ACS guidelines as well as lower likelihood of meeting the body mass index (BMI), physical activity, and alcohol recommendations (3).

The role of positive changes in neighborhood-level socioeconomic status (SES)—through the process of gentrification—on the health of residents remains unclear, with a growing body of literature presenting mixed or null results (38–40). According to Smith (41), gentrification is defined as “the process by which central urban neighborhoods that have undergone disinvestments and economic decline experience a reversal, reinvestment, and the in-migration of a well-off middle and upper-middle-class population.” On one end, gentrification may promote healthy lifestyles by increasing access to community resources such as parks, recreational areas, and healthy food options (42, 43). On the other end, gentrification may produce chronic stress by altering social networks and community cohesion (44, 45) and lead to voluntary or involuntary displacement of some residents due to increases in housing values and costs (46, 47). However, in a recent study of U.S. Hispanic/Latino adults, we reported no association between gentrification and change in income inequality with 6-year incidence of metabolic syndrome (39). Other studies on gentrification and health have found similar null or mixed associations [e.g., self-rated health (48), physical or mental health (49), incidence of hypertension (50), and mortality (51) among minoritized residents]. Gentrification may also influence income inequality and income polarization within communities that are undergoing an influx of new residents or displacement of long-standing residents (52, 53).

The intersection of low SES with residence in neighborhoods with rapidly changing income characteristics that make healthy lifestyles prohibitive despite being accessible, may amplify the risk of overweight and obesity. This in turn, may predispose Hispanic/Latino adults to developing obesity-related cancers and exacerbate existing cancer inequities (54, 55). To better understand how changing neighborhood economic environment influence lifestyle behavior change among U.S. Hispanic/Latino adults, our study aims to examine the

associations between neighborhood deprivation, neighborhood gentrification, and neighborhood change in income inequality with adherence to the 2012 ACS Guidelines on Nutrition and Physical Activity for Cancer Prevention (1).

## Materials and Methods

### Study Population

The Hispanic Community Health Study/Study of Latinos (HCHS/SOL) is a longitudinal multicenter, community-based cohort study that aims to characterize the prevalence and incidence of disease burden in diverse Hispanic/Latino adults in the United States (56, 57). Between 2008 and 2011, 16,415 noninstitutionalized Hispanic/Latino adults (ages 18–74 at baseline) were recruited and enrolled across four sites: Miami, FL; San Diego, CA; Chicago, IL; and the Bronx County, NY from areas with high concentrations of Hispanic/Latino residents and communities with low residential mobility to maximize retention rates in follow-up visits. Participants self-identified as Cuban ( $n = 2,348$ ), Dominican ( $n = 1,473$ ), Mexican ( $n = 6,472$ ), Puerto Rican ( $n = 2,728$ ), Central American, ( $n = 1,732$ ), and South American ( $n = 1,702$ ). Briefly, the sampling strategy included a stratified two-stage area probability sampling of census block groups and households across four U.S. cities. Additional details on the study sampling have been published (56, 57). At baseline, a battery of questionnaires was administered to assess demographic and lifestyle factors, and anthropometric measurements were obtained. This study used participant data at baseline. The study protocol was approved by all participating Institutional Review Boards, and the research was conducted in accordance with the ethical principles of the Declaration of Helsinki. Study participants provided written informed consent.

Baseline participant addresses were geocoded and linked to 2005–2009, 2006–2010, and 2012–2016 5-year Census tract estimates of the American Community Survey using the IPUMS National Historical Geographic Information System (58) and the National Neighborhood Change Database produced by Geolytics (59) and the 2000 decennial census using tracts.

### Neighborhood SES

#### Neighborhood Deprivation Index

This measure was operationalized using 2010 Census tracts by an approach developed by Messer (60) and described in detail for this cohort previously (3, 61). Briefly, we employed a principal component analysis to identify a score based on the shared variance of four variables representing neighborhood-level SES: (i) percent of residents with less than a high school diploma, (ii) percent of residents with household incomes below 100% of the federal poverty level, (iii) percent of residents who are unemployed, and (iv) median household income. The score was standardized to a mean of 0 and SD of 1. Interpretation is based on 1-SD changed; higher values indicate more deprivation.

#### Neighborhood Change in Income Inequality

The Gini coefficient of income distribution was downloaded from the IPUMS National Historical Geographic Information System (58), and based on American Community Survey 2005–09 and 2012–2016 datasets. The approach employed by IPUMS to calculate this measure was developed and described in detail by Shrider and colleagues (62). This index reflects how similar household income are across households within a given census tract, with values ranging from 0 (perfect equality) to 100 (perfect inequality; ref. 63). We estimated percent change in neighborhood income inequality using the following formula:  $[(\text{Gini}_{2012-16} - \text{Gini}_{2005-09}) / \text{Gini}_{2005-09} * 100]$ , as previously done by

others (64). A negative value in the change score indicates an improvement in income inequality, zero reflects no change, and a positive value reflects worsening income inequality over time. For this study, we scaled the coefficient to 10, thus, 1-unit change represents a 10% increase in inequality.

### Neighborhood Gentrification

Following prior studies, we used data from the 2000 decennial census and the 2006–10 American Community Survey to calculate an index of gentrification based on percent changes of: college or more educated adults ages 25 or more, number of residents living below the federal poverty line, and median household income (39, 51, 65). Higher values indicate greater gentrification. Interpretation is based on a 1-unit change, with higher values indicating greater gentrification.

### Neighborhood Immigrant Composition

Using the 2006–2010 American Community Survey data, we calculated percent of foreign-born residents in each census tract, with higher values representing a greater percent of foreign-born residents in a tract.

### American Cancer Society Guideline Adherence Score

For comparability with prior studies on American Cancer Society guideline adherence and cancer risk and outcomes among Hispanic/Latino adults (3–5), we operationalized the 2012 American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention (1), rather than the updated version on June 2022 (2) using baseline participant data.

### Diet

Diet data came from two 24-hour dietary recall interviews (66) that assessed intake of specific foods, including traditional and cultural foods (67). The diet components were scored according to the following cutoffs: (i) fruits and vegetables—1 point for consuming  $\geq 5$  servings/day and 0 otherwise; (ii) total carotenoids—0, 1, or 2 points for being in the first, second, or third tertile of carotenoid intake; (iii) red and processed meat—divided into quartiles and assigned scores of 0–3 (lowest quartile = 3); and (iv) whole grains, defined as percentage of whole grains consumed (whole grains/total grains) then divided into quartiles and assigned a score of 0–3 (lowest quartile = 0). A final diet score was obtained by summing across the four diet components that ranged from 0 to 9. Dietary adherence was then classified as low (0–2 diet points), moderate (3–6 diet points), and high (7–9 diet points) adherence. Of note, our interpretation of the American Cancer Society dietary guidelines reflects the approach used in prior studies of cancer outcomes in Hispanic/Latino adults (4, 5, 68). Data-driven interpretation of the guidelines was used when a recommendation did not call for a specific intake quantity.

### Alcohol

Alcohol intake as grams per day was obtained from the dietary recall and was scored separately from the diet score. One drink was defined as 14 g of pure alcohol (69). The alcohol recommendation was operationalized as 2 points for nondrinkers (high adherence) and 1 point for consuming up to 1 or 2 drinks per day for women and men (moderate adherence), respectively, and 0 points if exceeding the alcohol recommendations (low adherence).

### Physical Activity

Objective moderate to vigorous physical activity (MVPA) was captured using accelerometry-measured data derived from accelerometer that participants

wore for 7 days to assess frequency, duration, and intensity of their activity during that period. A detailed description of the accelerometer data has been published previously (70). The MVPA recommendation was operationalized as 2 points for engaging in  $\geq 150$  minutes/week of moderate or  $\geq 75$  minutes/week of vigorous activity per week (high adherence), 1 point for MVPA below recommended levels (moderate adherence), 0 points for 0 MVPA (low adherence).

### BMI

Anthropometric measures (height and weight) were collected during in-person visits to the study site including height to the nearest centimeter and weight to the nearest 0.1 kg. Self-reported weight and height at age 21 years were also collected at baseline and used when data were available. BMI was calculated using the formula  $\text{kg/m}^2$  and traditional cut-off points were used to indicate normal weight (BMI 18.5 to  $< 25.0 \text{ kg/m}^2$ ), overweight (25.0 to  $< 30.0 \text{ kg/m}^2$ ) and obesity ( $\geq 30.0\text{--}50 \text{ kg/m}^2$ ). The BMI recommendation was operationalized as 2 points for maintaining a BMI  $< 25 \text{ kg/m}^2$  at age 21 and at study entry (high adherence), 1 point for maintaining a BMI between 25 and  $30 \text{ kg/m}^2$  at either time (moderate adherence), and 0 points for BMI  $\geq 30 \text{ kg/m}^2$  at either point (low adherence).

### Composite Score

A composite guideline adherence score was derived from categorizations of dietary and alcohol intake, MVPA, and BMI components summed with possible range of “0” (does not meet recommendations) to “8” (meets all recommendations), and further categorized as low (0–3), moderate (4–5), and high (6–8) adherence.

### Covariates

We chose *a priori* confounders based on prior neighborhood studies in this population (3, 61), including health insurance status (yes, no), age categories (18–44, 45–65,  $> 65$ ), education ( $<$ high school, high school, some college,  $\geq$ college), household income ( $<$ \$30,000,  $\geq$ \$30,000, not reported), employment status (employed, unemployed), marital status (married/partnered, not married/partnered), smoking status (current, former, never), acculturation proxies [language preference (Spanish, English)], birthplace and duration of residence in the United States 50 states/DC (U.S. born, foreign/U.S. territory born  $< 10$  years, foreign/U.S. territory born  $\geq 10$  years), and Hispanic/Latino heritage. Neighborhood immigrant composition was defined as a neighborhood-level covariate.

### Statistical Analysis

All analyses accounted for HCHS/SOL complex survey sampling including stratification, clustering and sampling weights according to the guidelines established by the HCHS/SOL Coordinating Center. Separate sampling weights were used for analysis using accelerometry-measured variables. Of the 16,415 HCHS/SOL participants, 92.3% ( $N = 15,153$ ) returned the accelerometer, and 77.7% ( $N = 12,750$ ) provided at least 3 adherent days with 10 or more hours of wear time (70). Because of this large amount of missing accelerometry-measured outcomes ( $n = 3,933$ ), analyses in this study were adjusted for missing data using inverse probability weighting (71, 72). We excluded participants with missing data on variables of interest (not mutually exclusive): home addresses ( $n = 316$ ); residing outside of counties of interest ( $n = 370$ ); BMI at study entry ( $n = 428$ ); and intake of meat ( $n = 1,086$ ), grains ( $n = 1,086$ ), fruits ( $n = 1,086$ ), vegetables ( $n = 1,086$ ), nuts and legumes ( $n = 223$ ), and carotenoids

( $n = 434$ ). A missing indicator was used for sociodemographic factors, yielding an analytic sample of 11,909.

Weighted descriptive characteristics are provided for the total population. We calculated mean neighborhood scores by guideline adherence levels. We used multinomial logistic regression models to estimate the relative risk ratio (RRR) and 95% confidence interval (CI) of adherence to overall American Cancer Society guidelines by neighborhood measures. Given the clinical effects of smoking and smoking cessation on body weight (73), associations were also examined in a sample restricted to never smokers. In exploratory analysis, we also modeled individual guideline components to investigate whether overall guideline adherence driven by individual components. The proportional odds/parallel lines assumptions were examined using Akaike information criterion (AIC) and Bayesian information criterion (BIC) indices (74). Given that AIC and BIC were inconsistent, we also estimated ordered logistic regression models (OR and 95% CI estimates) and provide them as Supplementary Tables. Correlations between neighborhood indices are also provided in the Supplementary Tables.

We built three models to investigate the roles of potential confounders. In model 1, we adjusted for individual-level characteristics including, age, sex, marital status, acculturation, and insurance status. Model 2 adjusted for individual-level education and household income. Because some neighborhood risk factors may be confounders for other exposures, model 3 for the Gini income inequality index also added the neighborhood deprivation index and neighborhood immigrant composition, while models of gentrification additionally added neighborhood immigrant composition. All analyses were conducted using STATA 16 (75) and considered statistically significant at  $P < 0.05$ .

### Data Availability Statement

Data are maintained by the Hispanic Health Community Study/Study of Latinos and are available upon submitting a proposal to be approved by the publications committee. For more information, visit <https://sites.csc.unc.edu/hchs/>. Data can also be accessed at National Heart Lung and Blood Institute (NHLBI) BioLINCC and in Database of Genotype and Phenotype (dbGaP), NIH maintained database of datasets and was developed to archive and distribute the results of studies that have investigated the interaction of genotype and phenotype. <https://www.ncbi.nlm.nih.gov/gap/>

## Results

In this population, the majority were ages 18–44 (57%), female (52%), not married (75%), had less than a high school education (33%), had incomes less than \$30,000 (61%), were insured (50%), were foreign born and residing in the United States <10 years (51%), and had a Spanish language preference (76%; Table 1). Overall, 14%, 60%, and 26% of adults were classified as being low, moderately, or highly adherent, respectively, to the guidelines for cancer prevention.

Overall, Hispanic/Latino adults with high (weighted mean  $\pm$  SE:  $-0.14 \pm 0.06$ ) or moderate ( $-0.03 \pm 0.05$ ) guideline adherence lived in neighborhoods with lower deprivation relative to adults with low guideline adherence ( $0.07 \pm 0.07$ ;  $F$  statistic = 19.77,  $P < 0.001$ ; Table 2). Moderate levels of income inequality were found for high ( $4.42 \pm 0.03$ ), moderate ( $4.36 \pm 0.03$ ), and low ( $4.35 \pm 0.03$ ;  $F$  statistic = 8.94,  $P < 0.0001$ ) guideline adherence, although the qualitative differ-

**TABLE 1** Weighted baseline characteristics of U.S. Hispanic/Latino adults, recruited from 2008–2011,  $N = 11,909$

Participant characteristics	No. of participants	Weighted %
<i>Age, y</i>		
18–44	4,530	57.0
45–65	6,363	33.8
>65	1,016	9.2
<i>Female</i>		
7,158		51.5
<i>Married</i>		
2,983		25.1
<i>Education</i>		
< High school	4,604	33.0
High School	3,006	27.6
Some college	1,474	12.3
$\geq$ College	2,814	27.1
<i>Household income</i>		
Less than \$30,000	7,636	60.8
\$30,000 or more	3,647	32.5
<i>Has health insurance</i>		
6,045		50.2
<i>Place of birth</i>		
US/Territory born	2,759	27.7
Foreign born in United States	7,253	51.2
<10 years		
Foreign born in United States	1,897	21.1
$\geq$ 10 years		
<i>Self-reported heritage</i>		
Central American/South American	1,227	7.4
Cuban	1,088	19.0
Dominican	1,582	10.2
Mexican	4,895	38.7
Puerto Rican	1,953	15.9
South American	821	5.12
More than one/other heritage	333	3.6
<i>Spanish language preference</i>		
9,733		76.4
<i>Study site</i>		
the Bronx	2,941	24.7
Chicago	3,276	27.5
Miami	2,742	23.0
San Diego	2,950	24.8
<i>American Cancer Society Guideline adherence category (1)</i>		
Low	1,701	14.3
Moderate	7,125	59.8
High	3,083	25.9

ences are minimal. Low levels of gentrification were observed for high ( $0.22 \pm 0.13$ ), moderate ( $0.09 \pm 0.12$ ), and low ( $0.12 \pm 0.16$ ;  $F$  statistic = 0.31,  $P = 0.734$ ) guideline adherence groups.

### Associations for Overall American Cancer Society Guideline Adherence

A 1-SD increase in the NDI was associated with a 13% decrease in the likelihood of high versus low guideline adherence (RRR = 0.87, 95% CI = 0.78–0.98),

**TABLE 2** Weighted<sup>a</sup> mean and SE for measures of change in neighborhood SES of U.S. Hispanic/Latino adults, by American Cancer Society Guideline Adherence

	No. of study participants	American Cancer Society Guideline Adherence Categories <sup>b</sup>			F statistic	P
		Low	Moderate	High		
Neighborhood deprivation index <sup>c</sup>	11,909	0.07 ± 0.07	-0.03 ± 0.05	-0.14 ± 0.06	19.77	<0.001
Neighborhood change in income inequality <sup>d</sup>	11,909	4.42 ± 0.03	4.36 ± 0.02	4.35 ± 0.03	8.94	<0.0001
Gentrification <sup>e</sup>	11,905	0.12 ± 0.15	0.09 ± 0.11	0.22 ± 0.13	0.31	0.734

Abbreviations: SE, standard error; SD, standard deviation.

<sup>a</sup>Analysis accounted for inverse probability weights for missing accelerometry data.

<sup>b</sup>Operationalization of the guideline adherence categories have been described in Table 1.

<sup>c</sup>Neighborhood deprivation index was calculated using 2010 census tract data, using principal component analysis with for six variables: percent of residents with less than a high school diploma, percent of residents with household incomes below 100% of the federal poverty level, percent of residents who are unemployed, and median household income. The score was standardized to have a mean of 0 and SD 1. Lower values of the index indicate lower deprivation and higher values indicate higher deprivation.

<sup>d</sup>Change in income inequality was measured using the 2005–2009 and the 2012–2016 Gini coefficient of income distribution to estimate the absolute percent change in income inequality percent change, scaled to 10. The Gini coefficient of income distribution can range from 0 (perfect equality) to 100 (perfect inequality), thus, a 1-unit change represents a 10% increase in inequality.

<sup>e</sup>Gentrification was operationalized using data from the 2000 decennial census and the 2006–10 American Community Survey, to calculate an index that captured percent change of college or more educated adults aged 25 or more, number of residents living below the federal poverty line, and median household income. Interpretation is based on a 1-unit change, with higher values indicate greater gentrification.

while no association was found for moderate adherence (RRR = 0.96, 95% CI = 0.86–1.06; Table 3). Adjusting for individual level SES attenuated the association for high guideline adherence (RRR = 0.89, 95% CI = 0.80–1.00). No

associations were found between the Gini income inequality index or the gentrification index and overall guideline adherence score. Further adjustments for individual- or neighborhood-level covariates did not change these associations.

**TABLE 3** Multinomial associations between measures of change in neighborhood SES of U.S. Hispanic/Latino adults and adherence to the 2012 American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention

	American Cancer Society Guideline Adherence Categories <sup>a</sup>						
	Model 1, RRR (95% CI) <sup>b,c</sup>			Model 2, RRR (95% CI) <sup>b,d</sup>		Model 3, RRR (95% CI) <sup>b,d</sup>	
	Low	Moderate	High	Moderate	High	Moderate	High
Neighborhood deprivation index <sup>e</sup>	1.00	0.96 (0.86–1.06)	0.87 (0.78–0.98)	0.97 (0.87–1.07)	0.89 (0.80–1.00)	NA	NA
Neighborhood change in income inequality <sup>d</sup>	1.00	0.98 (0.80–1.20)	1.10 (0.89–1.37)	0.98 (0.80–1.20)	1.12 (0.89–1.40)	0.98 (0.80–1.21)	1.17 (0.93–1.48)
Gentrification <sup>f</sup>	1.00	0.99 (0.95–1.03)	1.02 (0.97–1.07)	0.99 (0.95–1.03)	1.02 (0.97–1.07)	0.98 (0.94–1.02)	1.01 (0.96–1.06)

Abbreviation: RRR, Relative Risk Ratio; SES, socioeconomic status; CI, Confidence Interval, SD, standard deviation.

<sup>a</sup>Operationalization of the guideline adherence categories is described in Table 1.

<sup>b</sup>Analysis accounted for inverse probability weights for missing accelerometry data.

<sup>c</sup>Model 1 adjusted for individual level covariates: age (18–44, 45–65, >65), sex (female, male), married (yes/no), health insurance status (insured/uninsured), combined nativity and years in the U.S. (foreign born and <10 years in U.S., foreign born and 10+ years in U.S., US born), language preference (Spanish, English), Heritage (Central or South American/more than 1 heritage/other, Cuban, Dominican, Mexican, Puerto Rican), study site (the Bronx, Chicago, Miami, San Diego).

<sup>d</sup>Model 2 additionally added individual-level socioeconomic status covariates: education (<high school, high school or GED, some college, college), household income (less than \$30,000, \$30,000 or more, missing).

<sup>e</sup>Model 3 added neighborhood-level covariates: percent foreign born (continuous) and neighborhood deprivation index.

<sup>f</sup>Operationalization of each neighborhood measure is described in Table 2. Neighborhood deprivation is interpreted as a 1-SD change with lower values of the index indicate lower deprivation and higher values indicate higher deprivation; Gini income inequality is interpreted as 10-unit change, thus, a 1-unit change represents a 10% increase in inequality; Gentrification index is interpreted as a 1-unit change, with higher scores reflecting greater gentrification.

**TABLE 4** Multinomial logistic regression for the associations between measures of change in neighborhood SES and individual components of the 2012 American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention

	Neighborhood deprivation index <sup>a,b</sup>	Neighborhood change in income inequality <sup>a,b</sup>	Gentrification <sup>a,b</sup>
No. of study participants	11,909	11,909	11,905
	RRR (95% CI)		
American Cancer Society Guideline Components <sup>c,d</sup>			
Alcohol <sup>c,d</sup>			
Low	1.00	1.00	1.00
Moderate	0.88 (0.74–1.04)	0.98 (0.69–1.41)	1.00 (0.93–1.08)
High	0.99 (0.83–1.18)	1.16 (0.82–1.64)	0.96 (0.90–1.03)
Dietary <sup>c,e</sup>			
Low	1.00	1.00	1.00
Moderate	0.97 (0.90–1.04)	0.96 (0.84–1.10)	1.04 (1.01–1.07)
High	0.92 (0.79–1.07)	1.03 (0.75–1.41)	1.02 (0.97–1.07)
Body mass index <sup>c,e</sup>			
Low	1.00	1.00	1.00
Moderate	0.90 (0.84–0.97)	0.98 (0.85–1.12)	0.99 (0.96–1.02)
High	0.86 (0.79–0.95)	1.05 (0.88–1.26)	1.00 (0.96–1.04)
Body mass index <sup>c,e,f</sup>			
Low	1.00	1.00	1.00
Moderate	0.86 (0.78–0.95)	1.05 (0.88–1.26)	0.97 (0.93–1.01)
High	0.87 (0.77–0.97)	1.13 (0.91–1.41)	0.97 (0.92–1.03)
Physical activity <sup>c,d</sup>			
Low	1.00	1.00	1.00
Moderate	0.93 (0.73–1.19)	0.79 (0.50–1.23)	1.05 (0.97–1.13)
High	0.99 (0.76–1.30)	1.02 (0.64–1.62)	1.06 (0.98–1.15)

Abbreviation: RRR, Relative Risk Ratio; SES, socioeconomic status; CI, Confidence Interval; SD, standard deviation.

<sup>a</sup>Operationalization of each neighborhood measure is described in Table 2. Neighborhood deprivation is interpreted as a 1-SD change with lower values of the index indicate lower deprivation and higher values indicate higher deprivation; Gini income inequality is interpreted as 10-unit change, thus, a 1-unit change represents a 10% increase in inequality; Gentrification index is interpreted as a 1-unit change, with higher scores reflecting greater gentrification.

<sup>b</sup>All models adjusted for individual level covariates: age (18–44, 45–65, >65), sex (female, male), married (yes/no), health insurance status (insured/uninsured), combined nativity and years in the U.S. (foreign born and <10 years in U.S., foreign born and 10+ years in U.S., US born), language preference (Spanish, English), Heritage (Central or South American/more than 1 heritage/other, Cuban, Dominican, Mexican, Puerto Rican), study site (the Bronx, Chicago, Miami, San Diego), education (<high school, high school or GED, some college, college), household income (less than \$30,000, \$30,000 or more, missing). Gentrification and Gini income inequality models additionally adjusted for percent foreign born (continuous), while Gini income inequality models also added neighborhood deprivation index.

<sup>c</sup>Operationalization of the American Cancer Society guideline adherence categories is described in Table 1.

<sup>d</sup>Analysis accounted for inverse probability weights for missing accelerometry data.

<sup>e</sup>Analysis accounted for complex survey weights for study design.

<sup>f</sup>Sample restricted to never smokers.

### Exploratory Analysis with ACS Components

Table 4 provides estimates for the multinomial associations between neighborhood measures and individual guideline components. For recommendations regarding BMI, a one-SD increase in the NDI was associated with a 10% lower risk of being in the moderate adherence group (95% CI = 0.84–0.97) and 14% lower risk of being in the high adherence group (95% CI = 0.79–0.95) instead of the low adherence group. There was evidence of a statistically significant and positive association between gentrification and meeting the dietary guidelines moderately (low vs. moderate adherence RRR = 1.04, 95%

CI = 1.01–1.07), but not high adherence (low vs. high adherence RRR = 1.02, 95% CI = 0.97–1.07). Gentrification was not associated with any other guideline components; while change in income inequality was not associated with any guideline components.

### Exploratory Analysis Restricted to Never Smokers

Among 7,236 Hispanic/Latino adults who were never smokers (Table 5), a 1-unit increase in the NDI was associated with a 16%–18% decrease in high versus low overall guideline adherence (model 1 RRR = 0.82, 95% CI = 0.71–0.95; model 2 RRR = 0.84, 95% CI = 0.84, 95% CI = 0.72–0.97). Neighborhood

**TABLE 5** Multinomial associations between measures of change in neighborhood SES of U.S. Hispanic/Latino adults and adherence to the 2012 American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention, Restricted to 7,236 Never Smokers

	ACS Guideline Adherence Categories <sup>a</sup>						
	Model 1, RRR (95% CI) <sup>b,e</sup>			Model 2, RRR (95% CI) <sup>c,e</sup>		Model 3, RRR (95% CI) <sup>d,e</sup>	
	Low	Moderate	High	Moderate	High	Moderate	High
Neighborhood deprivation index <sup>f</sup>	1.00	0.91 (0.80–1.03)	0.82 (0.71–0.95)	0.93 (0.82–1.05)	0.84 (0.72–0.97)	NA	NA
Neighborhood change in income inequality <sup>f</sup>	1.00	0.92 (0.70–1.21)	1.04 (0.78–1.39)	0.93 (0.70–1.22)	1.06 (0.80–1.42)	0.94 (0.71–1.25)	1.14 (0.84–1.53)
Gentrification <sup>f</sup>	1.00	0.99 (0.94–1.03)	1.01 (0.95–1.08)	0.98 (0.94–1.03)	1.01 (0.95–1.08)	0.98 (0.94–1.03)	1.01 (0.95–1.08)

Abbreviation: RRR, Relative Risk Ratio; SES, socioeconomic status; CI, Confidence Interval; SD, standard deviation.

<sup>a</sup>Operationalization of the guideline adherence categories is described in Table 1.

<sup>b</sup>Model 1 adjusted for individual level covariates: age (18–44, 45–65, >65), sex (female, male), married (yes/no), health insurance status (insured/uninsured), combined nativity and years in the U.S. (foreign born and <10 years in U.S., foreign born and 10+ years in U.S., US born), language preference (Spanish, English), Heritage (Central or South American/more than 1 heritage/other, Cuban, Dominican, Mexican, Puerto Rican), study site (the Bronx, Chicago, Miami, San Diego).

<sup>c</sup>Model 2 additionally added individual-level socioeconomic status covariates: education (<high school, high school or GED, some college, college), household income (less than \$30,000, \$30,000 or more, missing).

<sup>d</sup>Model 3 added neighborhood-level covariates: percent foreign born (continuous) in all models and neighborhood deprivation index in the Gini income inequality models.

<sup>e</sup>Analysis accounted for inverse probability weights for missing accelerometry data.

<sup>f</sup>Operationalization of each neighborhood measure is described in Table 2. Neighborhood deprivation is interpreted as a 1-standard deviation change with lower values of the index indicate lower deprivation and higher values indicate higher deprivation; Gini income inequality is interpreted as 10-unit change, thus, a 1-unit change represents a 10% increase in inequality; Gentrification index is interpreted as a 1-unit change, with higher scores reflecting greater gentrification.

gentrification and change in income inequality were not associated with overall guideline adherence among never smokers. Given the interactive effects between smoking and obesity (73), the BMI recommendations were further examined among never smokers (Table 4), which remained robust to this exclusion (low vs. moderate adherence, RRR = 0.86, 95% CI = 0.7800.95; low vs. high adherence, RRR = 0.87, 95% CI = 0.77–0.97).

### Sensitivity Analysis Using Ordinal Logistic Regressions Modeling

Most analyses were confirmed in the ordinal logistic regression models with some notable differences (Supplementary Tables S1–S3). The magnitude of association between neighborhood deprivation index and overall guideline adherence was more attenuated, ranging from 6% to 7% lower likelihood of guideline adherence for each 1-unit increase in neighborhood deprivation (model 1 OR = 0.92, 95% CI = 0.99–0.98; model 2 OR = 0.93, 95% CI = 0.87–0.99, Supplementary Table S1). Findings were similar and of slightly stronger magnitude for analysis restricted to never smokers (Supplementary Table S2).

Weak to moderate correlations were observed between cross-sectional and longitudinal neighborhood SES indices with neighborhood deprivation and Gini income inequality being the highest, 0.38 (Supplementary Table S4).

### Discussion

In this large community-based study of 11,909 U.S. Hispanic/Latino adults representative of populations living in the Bronx, Chicago, Miami, and San Diego, we examined the roles of neighborhood socioeconomic change measures on adherence to healthful lifestyles in accordance with the American Cancer Society guidelines on nutrition, physical activity, and BMI for cancer preven-

tion. In our stepwise multivariable adjusted analysis, we found evidence of an inverse association between neighborhood deprivation and guideline adherence. Hispanic/Latino adults residing in neighborhoods with increasing deprivation were 11%–18% less likely to have high overall guideline adherence relative to adults with low adherence. Of note, this association was attenuated with the inclusion of individual level SES in the model, suggesting that individual's baseline SES may serve as a buffer to their residential economic environment. We also found evidence of a negative association between neighborhood deprivation and individual guideline components: higher neighborhood deprivation associated with a 10%–14% lower likelihood to meet the BMI recommendations. Our findings corroborate prior work by several authors of this study has linked neighborhood deprivation (measured by residence level buffer) to BMI at baseline and changes in BMI over time among the San Diego subsample of Hispanic/Latino adults participating in the HCHS/SOL study (76).

Given their history of disinvestment, communities of color are at high risk of gentrification (77, 78) as cities now look to “revitalize” and “regenerate” these socioeconomically and racially segregated neighborhoods through new or improved developments in housing and commerce, creation of green spaces, and bringing in healthy food options like high-end grocery stores and farmers markets (42, 79). While long-time residents of these areas ought to benefit from improvements to their neighborhood, they are often excluded from the process, facing significant displacement to their businesses, political power, and social and cultural capital (38, 46, 47, 80). Long-time residents are also vulnerable to voluntary or involuntary physical displacement—and likely resegregation to environments that are worse off than their original place of residency (40, 81). Because of these vulnerabilities, it is hypothesized that gentrification may protect the health of more privileged residents rather than that of less

privileged residents (40). In addition, gentrification may widen income gaps thereby exacerbating income inequality (38), with areas undergoing gentrification experiencing growing income inequality (82), which in turn is also linked to health inequities (83) and mortality (84, 85).

The literature on gentrification and change in income inequality and objective health measures remains scarce. Prior studies have linked increasing income inequality to worse health outcomes including adverse lifestyle behaviors (i.e., lower fruit and vegetable consumption; refs. 84–86). Contrary to this literature, we found that increasing income inequality did not associate with adherence to the overall guidelines or the individual guideline components. The null association in our study may be in part explained by the use of tract-level Gini index for income inequality which is distinct from all prior work that measured it at larger scales (i.e., state, counties, cities). Generally, studies have shown the gentrification is not associated with improved self-rated health (48), incidence of metabolic syndrome (39) or hypertension (50), and mortality (51) or may actually lead to worse outcomes (87) among minoritized residents relative to non-Hispanic White residents. Our findings are consistent with the hypothesis that gentrification may not directly benefit minoritized individuals in communities of color undergoing gentrification. Although retail and green gentrification may introduce high-quality physical activity resources (green spaces, recreational amenities) and supermarkets with higher quality foods (40), unaffordable rent and food prices may lead to food insecurity (88) among low-income residents and displacement for long-standing residents in the later stages of gentrification, especially in neighborhoods that undergo food gentrification (40, 88). Any benefits of gentrification in communities of color may only hold for residents of higher socioeconomic standing (89). For example, a study by Schnake-Mahl and colleagues among non-Hispanic Black, low-income mothers, found no association between displacement to a gentrified neighborhood with BMI and self-reported physical or mental health (49). Future studies that examine interactions between gentrification and individual SES are warranted. Previously, several authors of this study reported no association between gentrification and change in income inequality with 6-year incidence of metabolic syndrome among Hispanic/Latino adults (39). Consistent with these findings, in the current study, we found that gentrification or change in income inequality were not associated with the overall American Cancer Society guideline recommendations and individual guideline components like physical activity or alcohol intake. However, contrary to the existing literature, we found evidence suggesting a benefit of gentrification on dietary patterns. There are two notable factors that may contribute to this association. First, our measure of dietary adherence was based on operationalization of the 2012 guidelines (90) which did not incorporate operationalization of sugar-sweetened beverages unlike more recently updated guidelines (2) or other commonly used diet quality scales like the Healthy Eating Index (91). Future studies should examine this association further with other measures of diet quality and patterns. Second, it is important to note that HCHS/SOL participants may reside in neighborhoods that are at early stages of gentrification. Betancur and colleagues suggest that in the short term, gentrification may exert positive effects among Hispanic/Latino communities. However, in the long term, gentrification may have negative health effects via physical and sociocultural displacement and resource competition (92, 93). It is plausible that the full health effects of gentrification may be better captured over time through use of longitudinal or life course data or at a different geographical unit (e.g., block). In addition, the gentrification of Hispanic/Latino communities often occurs block to block with displacement manifesting at the block-level, resulting in residential mobility and reseg-

regation due to unaffordable rent, increases in housing discrimination and ethno-racial profiling (94–96). This study lacked block-level census data. Furthermore, it is plausible that residents benefiting from gentrification may have higher socioeconomic standing, which this study was unable to disentangle due to insufficient power. Finally, given that income inequality is a process interrelated with gentrification, a nonsignificant relationship is in line with those of the gentrification models. Future work should examine types, stages, and other gentrification-related processes to better understand the role of gentrification as it develops over time on cancer-related disparities. This information may guide tailoring of cancer preventive interventions for at risk Hispanic/Latino communities.

Important strengths of this study include the use of probability sampling that enabled generalizability to the Hispanic/Latino target communities surrounding the study sites in the Bronx, Chicago, Miami, and San Diego compared with convenience samples (56). The use of validated dietary scales which considered cultural/traditional dietary patterns among Hispanic/Latino adults and objectively measured physical activity and BMI, captured behaviors more accurately. However, these measurements were taken at baseline, which prevent us from accounting for behavior changes over time and as guidelines have become more widely disseminated and awareness about them has increased. Our geocodes were coded to the census tract level and captured only at baseline. Therefore, we are unable to disentangle effects related to length of residence in a particular neighborhood and participant mobility (voluntary or involuntary) in and out of the baseline address (97). There is wide heterogeneity in how gentrification is measured (98) and our selected measurement may not fully or adequately capture the process of gentrification.

In conclusion, neighborhood deprivation, but not gentrification or changes in income inequality, was related to adherence to the 2012 American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention. Our study suggests a need for community and population level interventions to increase uptake of healthful lifestyle behaviors to reduce cancer risk among the growing and aging U.S. Hispanic/Latino adult population residing in areas with high economic deprivation. Our study provides further evidence that gentrification or changes in income inequality of a neighborhood may not directly influence the health behaviors of Hispanic/Latino residents of these communities.

## Authors' Disclosures

G.A. Talavera reports grants and personal fees from NIH during the conduct of the study. L.C. Gallo reports grants from NIH during the conduct of the study; grants from NIH outside the submitted work. M.L. Daviglius reports grants from NIH during the conduct of the study. A. Pirzada reports grants from NIH during the conduct of the study. K.M. Perreira reports grants from NHLBI during the conduct of the study. D. Sotres-Alvarez reports grants from NHLBI during the conduct of the study. J.J. Plascak reports Invited, paid speaker at a National Comprehensive Cancer Network meeting in June 2023. No disclosures were reported by the other authors.

## Disclaimer

The contents of this article are solely the responsibility of the authors and do not necessarily represent the official position of the NIH, the U.S. Department of Health and Human Services, or the federal government.



## Authors' Contributions

**M.S. Pichardo:** Conceptualization, software, formal analysis, validation, investigation, visualization, methodology, writing-original draft, project administration, writing-review and editing. **C.M. Pichardo:** Conceptualization, formal analysis, validation, investigation, methodology, writing-original draft, writing-review and editing. **G.A. Talavera:** Resources, data curation, supervision, funding acquisition, methodology, project administration, writing-review and editing. **L.C. Gallo:** Conceptualization, resources, data curation, supervision, project administration, writing-review and editing. **C.C. Kuo:** Writing-review and editing. **S.F. Castañeda:** Data curation, validation, methodology, writing-review and editing. **E.C. Chambers:** Writing-review and editing. **M.L. Daviglius:** Writing-review and editing. **A. Pirzada:** Writing-review and editing. **K.M. Perreira:** Data curation, validation, methodology, writing-review and editing. **D. Sotres-Alvarez:** Data curation, funding acquisition, methodology, writing-review and editing. **T.Y. Peña Ortiz:** Writing-review and editing. **J.J. Plascak:** Formal analysis, supervision.

## Acknowledgments

The authors thank the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) participants, who generously contributed their time and provided the study data. The authors also thank the HCHS/SOL staff members for their dedication and expertise. A complete list of staff and investigators was published in the *Annals of Epidemiology* 2010; 20:642–649 and is also available on the study website (<http://www.csc.unc.edu/hchs>).

**Funding:** The Hispanic Community Health Study/Study of Latinos is a collaborative study supported by contracts from the National Heart, Lung, and Blood Institute (NHLBI) to the University of North Carolina (HHSN268201300001I/N01-HC-65233), University of Miami (HHSN268201300004I/N01-HC-65234), Albert Einstein College of Medicine (HHSN268201300002I/N01-HC-65235), University of Illinois at Chicago (HHSN268201300003I/N01-HC-65236 Northwestern University), and San Diego State University (HHSN268201300005I/N01-HC-65237). The following Institutes/Centers/Offices have contributed to the HCHS/SOL through a transfer of funds to the NHLBI: National Institute on Minority Health and Health Disparities, National Institute on Deafness and Other Communication Disorders, National Institute of Dental and Craniofacial Research, National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Neurological Disorders and Stroke, NIH Institution-Office of Dietary Supplements. E.C. Chambers was supported by National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) of the NIH (grants P30DK111022 and R01DK121896).

## Note

Supplementary data for this article are available at Cancer Research Communications Online (<https://aacrjournals.org/cancerrescommun/>).

Received June 26, 2023; revised August 03, 2023; accepted September 05, 2023; published first October 02, 2023.

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