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Metropolitan-level ethnic residential segregation, racial identity, and body mass index among U.S. Hispanic adults: a multilevel cross-sectional study

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Abstract

Background: The few studies that have examined whether metropolitan-level ethnic residential segregation is associated with obesity among Hispanics are mixed. The segmented assimilation theory, which suggests patterns of integration for immigrant groups varies by social factors, may provide an explanation for these mixed findings. In this study we examined whether one social factor, racial identity, modified the association between ethnic residential segregation and body mass index (BMI) among Hispanics.

Methods: We used data on 22,901 male and 37,335 non-pregnant female Hispanic adult participants of the 2003–2008 U.S. Behavioral Risk Factor Surveillance System living in 227 metropolitan or micropolitan areas (MMSAs). Participants self-identified as White, Black, and 'some other race'. BMI was calculated using self-reported height and weight; the Hispanic isolation index was used to measure Hispanic residential segregation. Using multi-level linear regression models, we examined the association of Hispanic residential segregation with BMI, and we investigated whether this relationship varied by race.

Results: Among men, Hispanic segregation was unassociated with BMI after adjusting for age, race, MMSA-level poverty, and MMSA-level population size; there was no variation in this relationship by race. Among women, significant associations between Hispanic segregation and BMI in models adjusted for demographics and MMSA-level confounders became attenuated with further adjustment for education and language of exam. However, there was statistically significant variation by race ($P_{\text{interaction}} = 0.03$ and 0.09 for Hispanic Blacks and Hispanics who identified as some other race, respectively, vs. Hispanic Whites). Specifically, higher segregation was associated with higher mean BMI among Hispanic Whites, but it was associated with lower mean BMI among Hispanic Blacks. Segregation was unassociated with BMI among Hispanic women identifying as some other race.

Conclusions: This heterogeneity highlights the persistent influence of race on structural processes that can have downstream consequences on health. As Hispanics grow as a proportion of the U.S. population, especially across urban centers, understanding the health consequences of residence in segregated areas, and whether or not these impacts vary across different groups, will be important for the design of more comprehensive solutions to prevent adverse health outcomes.

Keywords: Hispanics, Residential segregation, Body mass index, Race, Health disparities

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Background

Hispanics are the fastest growing minority group in the U.S., constituting over 16% of the total population, and accounting for more than half of the nation's population growth in the last decade [1]. Similar to non-Hispanic Blacks, Hispanics carry a disproportionate burden of obesity relative to non-Hispanic Whites. Continuation of this patterning will have implications for future chronic disease burden in the U.S. Thus, a better understanding of the factors that contribute to obesity among Hispanics will help to better target public health prevention efforts.

A growing body of research suggests that contextual factors may influence obesity and contribute to racial and ethnic disparities [2-6]. Metropolitan-level racial or ethnic residential segregation, a process that sorts individuals into different neighborhoods by race or ethnicity, has been implicated as a fundamental cause of health disparities [7]. Residential location determines the availability and quality of economic and social resources including schools, safety, recreational amenities, and public transportation [7,8]. As a result, living in racially or ethnically segregated neighborhoods may also influence social, economic, and health outcomes [9].

Most studies of metropolitan-level racial segregation have focused on non-Hispanic Black populations and have shown that higher levels of segregation are associated with poorer health, including obesity, hypertension, and worse self-rated health [10-13]. However, it is unclear whether metropolitan-level residential segregation has the same implications for health among Hispanics. On the one hand, greater residential concentration of Hispanics is thought to be associated with higher area poverty, higher crime, and limited access to health-promoting resources [14,15]. On the other hand, it has also been associated with better social support and networks, and a greater availability of healthier food options [14,16-18]. Results from the few published empirical studies of metropolitan-level segregation and obesity among Hispanics are inconsistent. One study of metropolitan-level segregation and obesity in Mexican-Americans found higher segregation was associated with lower obesity among women; however there was no association among men [19]. In contrast, another study among Hispanics showed that higher segregation was associated with higher obesity; results were not presented separately for men and women [20].

These findings suggest there may be multiple, yet divergent pathways linking segregation to health. Given the heterogeneity of the Hispanic population, these mixed findings may also reflect variation in the impact of segregation across groups. For example, there is evidence that associations between segregation and health differ between men and women [19], and between immigrants and those born in the U.S. [21]. Another factor that may be a

significant source of variation in this relationship is race. Although routinely examined under a single racial/ethnic classification, Hispanics represent a diverse continuum on the racial spectrum from white to black. A growing proportion, approximately 42% according to the 2000 U.S. Census, also identify as 'some other race' [22]. One reason for this is that many Hispanics do not identify with existing race options and instead, choose the 'some other race' category because it better reflects a racialized Hispanic identity that aligns more closely with their Latin American mestizo heritage [23,24].

Several studies have shown that socially defined race among Hispanics influences health [25]. For example, a study of blood pressure in a community-based sample of Puerto Ricans found that darker skin color defined by cultural consensus was associated with higher blood pressure, particularly among higher socioeconomic status individuals [26]. However, they found no association between skin pigmentation measured by a reflectometer and blood pressure. In addition, a U.S. study comparing associations of self-identified and socially assigned race with self-rated health found that among participants who self-identified as Hispanic, those who were usually classified by other people as White had better self-rated health than those who were usually classified by other people as Hispanic [27]. These studies highlight the importance of socially constructed race as a determinant of health among Hispanics.

Residence in racially or ethnically segregated areas has historically been the first step in the assimilation process for race or ethnic groups who immigrate to the U.S., including Hispanics [28]. There are three competing theories relating to how residential patterns among recent immigrant groups change over time [29]. Spatial assimilation theory states that immigrants become integrated with the majority group over time as they adopt mainstream cultures and attitudes and as they rise in socioeconomic status [30]. Place stratification theory posits that immigrants will remain segregated from the majority group across generations due to factors like discrimination by the majority group [31]. The segmented assimilation theory suggests patterns of integration will vary due to social factors such as race [18].

Although race has long played a role in shaping residential patterns in the U.S. among non-Hispanics, it has been shown to do so among Hispanics as well. Data from the 2000 Census indicates that Hispanic Whites are less likely to be segregated from non-Hispanic Whites than Hispanic Blacks [29]. Moreover, there is evidence that Hispanic Blacks are just as segregated from non-Hispanic Whites as non-Hispanic Blacks are [23]. These findings suggest that race may be a salient factor in determining where Hispanics live, especially as they move away from ethnic enclaves and assimilate to the U.S. mainstream. If the residential options outside of

ethnic enclaves differ for Hispanic Blacks and Whites, then the health implications of living in an ethnic enclave could be expected to differ by race.

Using data from a large national sample of Hispanic men and women in the Behavioral Risk Factor Surveillance System (BRFSS), our study builds on existing research by examining the inter-relationships among residential segregation, racial identity, and body mass index (BMI). We investigated 1) whether Hispanic residential segregation is associated with differences in mean BMI and 2) whether the association between segregation and BMI varies by race. Only two other studies to our knowledge have assessed the association between metropolitan-level residential segregation and weight among Hispanics [19,20], and none have examined differences in this relationship by race. Consistent with the segmented assimilation theory, we hypothesized that associations of segregation with BMI would vary by race. As Hispanics grow as a proportion of the U.S. population, especially across urban centers, it will be important to understand the health consequences of residence in segregated areas, and whether or not these impacts vary across different groups.

Methods

Data source and study sample

This study used data from the 2003–2008 Behavioral Risk Factor Surveillance System (BRFSS). BRFSS is a cross-sectional, nationally representative random-digit-dial telephone survey administered annually by the Centers for Disease Control and Prevention [32]. The BRFSS survey was approved by the Institutional Review Boards of the Centers for Disease Control and Prevention and all participating states' Departments of Health. We restricted analyses to Hispanics aged 25 years and older living in U.S. metropolitan or micropolitan statistical areas (MMSAs) that self-identified as White, Black, or 'some other race.' This is consistent with the primary race classifications selected by the majority of U.S. Hispanics in the 2000 U.S. Census [22]. Data were pooled across 6 years (2003–2008) of the BRFSS to ensure sufficient sample size for Hispanic Blacks.

Measures

Outcome

BMI (weight in kilograms/height in meters squared) was calculated using self-reported height and weight, and was modeled continuously.

Hispanic residential segregation

Massey and Denton conceptualized five geographic dimensions of racial/ethnic residential segregation: evenness, exposure, clustering, centralization, and concentration [33]. All are empirically correlated, but each is thought to represent distinct aspects of residential segregation. In this study

the Hispanic isolation index, a measure of the exposure dimension, was used. The Hispanic isolation index estimates the extent to which Hispanics are only exposed to other Hispanics (of any race). The Hispanic isolation index was created using 2005–2009 American Community Survey data [34]. Census tracts were used as proxies for neighborhoods in these analyses. The isolation index is a commonly used measure with a well-documented theoretical pathway through which it is believed to influence health outcomes [33]. Specifically, it is hypothesized to lead to health disparities by concentrating poverty among minorities and leaving them more vulnerable to the adverse health outcomes associated with living in disadvantaged neighborhoods [35]. The isolation index represents the average neighborhood % Hispanic in which the average Hispanic lives within a given metropolitan/micropolitan area. It is represented mathematically as follows [33]:

$$\text{Isolation index} = xP^*_x = \sum_{i=1}^n \left[\frac{x_i}{X} \right] \left[\frac{x_i}{t_i} \right]$$

Where x_i is the number of Hispanics in census tract i , t_i is the total population in tract i and X is the number of Hispanics in the metropolitan area. This proportion is then summed across all n census tracts in the MMSA. MMSAs are geographic entities consisting of urban areas and surrounding counties that are tied economically or socially to the urban core. The isolation index was only computed for MMSAs that have at least 1000 Hispanics, since segregation indices for smaller minority populations are less reliable [29].

Covariates

Race was categorized as Black, some other race, and White. Age was modeled continuously, and a squared term was included to account for its non-linear relationship with BMI. Education and acculturation were adjusted for as individual-level factors that might account for associations of segregation with BMI. These factors could be confounders, but given that segregation is hypothesized to contribute to health disparities by influencing opportunities for socioeconomic mobility (e.g., through poor quality schools), these may also be mediators [7]. Education was categorized as less than high school completed, high school diploma or equivalent, and more than high school. Nativity (foreign-born vs. U.S.-born) was not available in the BRFSS data. Therefore, the language in which the interview was administered, non-English versus English, was included, instead, as a proxy for acculturation, a process recognized as an important determinant of health among Hispanics [36]. The MMSA population size and the percentage of the MMSA population living below the U.S. Census Bureau-defined poverty threshold [37] were also adjusted for in these analyses as confounders.

Analysis

All results were gender-stratified based on previous research showing differences in relationships of adversity and stress with eating behaviors and weight between men and women [38,39]. Of the 24,722 male and 42,577 non-pregnant female self-identified Hispanic Black, White, or some other race BRFSS participants aged 25 and older living in MMSAs with 1000 or more Hispanics, 1406 men and 4695 women were excluded for missing data on height or weight. An additional 415 men and 547 women were excluded for missing data on education or language of exam, yielding a sample of 22,901 men (842 Black, 11,982 White, and 10,077 some other race) and 37,335 women (1,421 Black, 19,978 White, and 15,936 some other race). Hispanic White men were less likely to have missing data than Hispanic Black or some other race men, while Hispanic women who identified as some other race were more likely to have missing data than Hispanic Black or White women.

Means with standard errors and frequencies were calculated for all continuous and categorical covariates by race, accounting for unequal selection probabilities. Continuous covariates were compared using analysis of variance and categorical variables were compared using the χ^2 statistic. Descriptive analyses also examined the distribution of Hispanic Blacks, Hispanic Whites, and Hispanics who identified as some other race across categories (based on quartiles) of MMSA-level Hispanic isolation index score, poverty, and population. We also examined the distribution of non-Hispanic Black and White isolation index scores among Hispanics living in the lowest quartile of the Hispanic isolation index score. This was done to evaluate whether there was evidence of segmented assimilation patterns among Hispanics living outside ethnic enclaves by race.

Multilevel linear regression was used to estimate associations between residential segregation, race, and BMI. A series of two-level random intercept models (with a random intercept for each MMSA) were fitted using the 22,901 male and 37,335 female study participants nested within 227 MMSAs. There was an average of 100.9 men and 164.5 women per MMSA. Since there was no evidence of a non-linear relationship between the Hispanic isolation index and BMI, the index was modeled continuously. Estimates of the association between the isolation index and BMI correspond to mean differences in BMI per 1-standard deviation (SD) unit increase in the isolation index score. The first model was adjusted for age, age², race, the Hispanic isolation index, and MMSA-level confounders. Subsequent models were additionally adjusted for the language of interview and education. To evaluate heterogeneity in this association by race, an interaction between race and the Hispanic isolation index was tested.

Individual-level sampling weights were incorporated into the multilevel models to account for the unequal selection probabilities of the participants. These weights were scaled so that the new weights summed to the level-2 (MMSA) cluster sample size [40]. Descriptive analyses were conducted using SAS survey procedures (SAS Institute, Cary, NC) and multilevel analyses were conducted using Mplus 6 (Muthén & Muthén, Los Angeles, CA).

Results

Table 1 shows sample characteristics by sex and race. Among men, mean BMI for Hispanic Blacks and Whites was the same, (28.1 kg/m²) and among Hispanics who identified as some other race, it was slightly higher (28.3 kg/m²). Hispanics who identified as some other race were younger and had less education than Hispanic Whites. There were also similar age and educational differences between Hispanic Black and White men, but these were not statistically significant. Among women, mean BMI was significantly higher among Hispanic Blacks (28.7 kg/m²) and Hispanics who identified as some other race (28.0 kg/m²) compared to Hispanic Whites (27.6 kg/m²). Hispanic Black and some other race women were also younger, and a smaller percentage interviewed in a non-English language. However, there were no race differences in educational attainment.

Table 2 depicts the distribution of Hispanic study participants by race and quartiles of MMSA-level Hispanic isolation index score, poverty, and population size. Since distributions were similar for men and women, they were combined in this table. Hispanic Blacks, Whites, and those who identified as some other race were represented in all quartiles of the MMSA-level characteristics. A smaller percentage of Hispanic Black participants were living in areas of high Hispanic segregation areas (8.4% of all Hispanic Blacks) compared to low segregation areas (36.0%); and a smaller percentage resided in small MMSAs compared to large MMSAs (15.4% and 37.4%, respectively). Hispanic Whites and those who identified as some other race were evenly distributed across the quartiles for each characteristic.

Among Hispanics that lived in low Hispanic segregation areas, almost 64% of Hispanic Blacks lived in areas characterized by a high non-Hispanic Black isolation score, compared with $\leq 32\%$ for Hispanic Whites and Hispanics who identified as some other race (Table 3). In contrast, over 50% of all Hispanic Whites that lived in low Hispanic segregation areas lived in areas characterized by a high non-Hispanic White isolation score. This was true of just 20% of Hispanic Blacks and under 32% of Hispanics who identified as some other race.

Among men, in both the minimally and fully adjusted model, segregation was unassociated with BMI (Table 4). There was no difference in mean BMI between Hispanic

Table 1 Sample characteristics of Hispanics in the 2003–2008 Behavioral Risk Factor Surveillance System (BRFSS) by sex and race

	Men			Women		
	Hispanic blacks (n = 842)	Hispanics who identified as some other race (n = 10,077)	Hispanic whites (n = 11,982)	Hispanic blacks (n = 1421)	Hispanics who identified as some other race (n = 15,936)	Hispanic whites (n = 19,978)
Body mass index, kg/m ² (SE)	28.1 (0.3)	28.3 (0.1)*	28.1 (0.1)	28.7 (0.4)*	28.0 (0.1)*	27.6 (0.1)
Age, years (SE)	41.2 (0.9)	40.4 (0.2)*	42.7 (0.2)	43.2 (0.8)*	42.0 (0.2)*	45.2 (0.2)
Education, %						
Less than high school	38.1	35.9*	31.8	31.6	31.2	31.7
High school	27.9	27.3	25.7	27.7	28.1	26.7
More than high school	33.9	36.8	42.6	40.7	40.7	41.6
Non-English questionnaire, %	41.2	43.9	43.3	36.6	39.2*	41.8

Abbreviation: SE = standard error.

*P < .05 for comparisons with Hispanic Whites.

Black and White men, but Hispanic men who identified as some other race had higher mean BMI compared with white Hispanic men. Less acculturated men (as measured by language of interview) had lower mean BMI than more acculturated men, and lower educational attainment was associated with higher BMI. The relationship between segregation and BMI did not vary by race ($P_{\text{interaction}} > 0.3$).

Among women, higher segregation was marginally associated with higher mean BMI (beta = 0.19 kg/m²; SE = 0.11)

after adjusting for age, race, and MMSA-level confounders. However, this relationship weakened after controlling for language of interview and education (beta = 0.07; SE = 0.11). Both Hispanic Black and some other race women had higher mean BMI than Hispanic White women. In addition, lower educational attainment was associated with higher BMI.

In contrast to findings among men, the relationship between Hispanic segregation and BMI varied by race among women ($P_{\text{interaction}}$ for Hispanic Blacks = 0.03,

Table 2 Distribution (shown as percentage) of MMSA-level characteristics by race among Hispanics in the 2003–2008 Behavioral Risk Factor Surveillance System (BRFSS)

Quartile of MMSA-level characteristic	Hispanic blacks (n = 2,263)	Hispanics who identified as some other race (n = 26,013)	Hispanic whites (n = 31,960)
Hispanic isolation index			
Q1 (<0.24)	36.0	25.5	26.8
Q2 (0.24 – 0.369)	23.5	25.5	18.7
Q3 (0.37 – 0.539)	32.0	26.0	24.0
Q4 (≥ 0.54)	8.4	23.0	30.5
Mean poverty ^a			
Q1 (< 10.7%)	30.5	26.1	23.8
Q2 (10.7% – 13.0%)	29.6	23.3	25.9
Q3 (13.1% – 15.3%)	15.9	21.6	25.8
Q4 (≥ 15.4%)	24.0	29.0	24.5
Population size			
Q1 (< 695,157)	15.4	24.8	24.2
Q2 (695,157 – 1,480,259)	21.7	27.7	23.4
Q3 (1,480,259 – 2,669,986)	25.5	26.8	24.3
Q4 (≥ 2,669,986)	37.4	20.7	28.2

Abbreviations: MMSA = metropolitan or micropolitan statistical area; Q = quartile.

^aPercentage of the MMSA population living below the 1999 U.S. Census Bureau-defined poverty threshold.

Table 3 Percentage of all Hispanic participants living in low Hispanic segregation areas^a by level of non-Hispanic residential segregation and race, 2003-2008 Behavioral Risk Factor Surveillance System (BRFSS)

	Hispanic blacks (n = 319)	Hispanics who identified as some other race (n = 1,469)	Hispanic whites (n = 2,702)
Quartile of non-hispanic black isolation index score			
NBI 1 (low)	9.1	43.5	41.0
NBI 2	2.5	5.0	5.6
NBI 3	24.8	21.0	21.4
NBI 4 (high)	63.6	30.5	32.0
Quartile of non-hispanic white isolation index score			
NWI 1 (low)	39.2	34.0	15.8
NWI 2	21.3	13.4	14.6
NWI 3	19.4	20.9	19.3
NWI 4 (high)	20.1	31.7	50.3

^aLow Hispanic segregation areas is defined as the lowest quartile of the Hispanic isolation index.
Abbreviation: NBI = Non-Hispanic Black isolation index score; NWI = Non-Hispanic White isolation index score.

$P_{\text{interaction}}$ for Hispanics who identified as some other race = 0.09) (Figure 1). Higher segregation was associated with higher mean BMI for Hispanic White women (beta = 0.17 kg/m²; SE = 0.11; $P = 0.11$) but with lower BMI for Hispanic Black women (beta = -0.54 kg/m²; SE = 0.34; $P = 0.12$). Segregation was unassociated with mean BMI for Hispanic women who identified as some other race (beta = -0.001 kg/m²; SE = 0.13; $P = 0.99$). Analogously, race differences in women were small in areas where Hispanic segregation was highest; but in areas of low segregation, there were considerable race disparities. To illustrate this we estimated associations of race with BMI at the lowest (0.24) and highest (0.54) quartiles of the Hispanic isolation index score. When

segregation was low, Hispanic Black (beta = 1.71; SE = 0.28; $P < 0.001$) and some other race (beta = 0.67; SE = 0.14; $P < 0.001$) women had significantly higher mean BMI than Hispanic White women. When segregation was high, these differences were much smaller (beta = 0.70; SE = 0.49; $P = 0.15$ for Hispanic Black women and beta = 0.43; SE = 0.10; $P < 0.001$ for Hispanic women who identified as some other race).

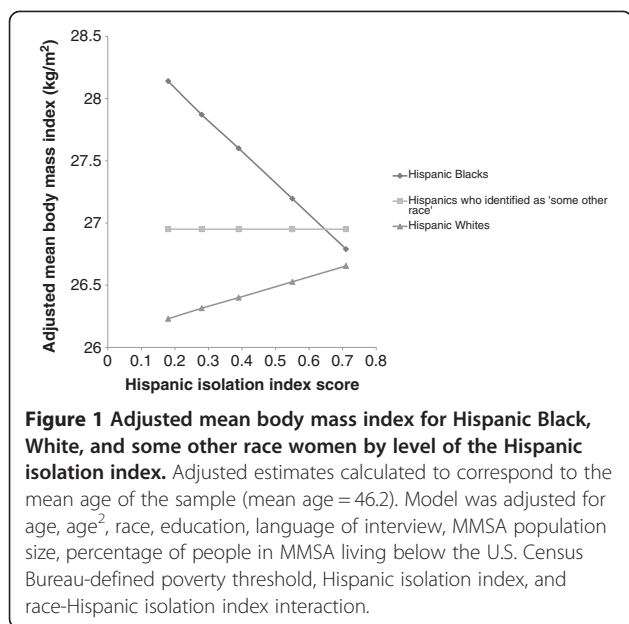
Discussion

We investigated the association between metropolitan-level ethnic residential segregation and BMI among Hispanics and whether this relationship varied by race. Hispanic segregation was unassociated with BMI among men, and there

Table 4 Gender-stratified adjusted mean differences (standard error) in body mass index among Hispanics in the 2003-2008 Behavioral Risk Factor Surveillance System (BRFSS)

	Men (n = 22,901)		Women (n = 37,335)	
	Model 1	Model 2	Model 1	Model 2
Hispanic isolation index	0.06 (0.12)	0.11 (0.13)	0.19 (0.11)*	0.07 (0.11)
Race				
Hispanic black	0.22 (0.26)	0.17 (0.26)	1.43 (0.31)**	1.39 (0.30)**
Hispanics who identified as some other race	0.26(0.10)**	0.29 (0.11)**	0.72 (0.11)**	0.55 (0.10)**
Hispanic white	ref	ref	ref	ref
Language of exam				
Non-English		-0.87 (0.12)*		-0.10 (0.14)
English		ref		ref
Education				
Less than high school		0.54 (0.14)**		2.19 (0.16)**
High school		0.57 (0.12)**		1.11 (0.10)**
More than high school		ref		ref

* $P < 0.10$; ** $P < 0.05$.
 All models are adjusted for age, age², MMSA-level poverty, and MMSA population size.
Abbreviation: MMSA = metropolitan or micropolitan statistical area.



was no variation by race. Among women, the association between segregation and BMI was accounted for by acculturation and education, individual-level factors that may be on the causal pathway linking segregation to BMI. There was also significant heterogeneity in this relationship by race. Specifically, higher segregation was associated with higher mean BMI for Hispanic White women, but with lower mean BMI among Hispanic Black women, and there was no association among Hispanic women who identified as some other race. We also found that race differences in BMI were smaller for women living in areas of high Hispanic segregation than those living in low Hispanic segregation areas.

Few studies have examined the relationship between metropolitan-level residential segregation and obesity in Hispanics, and findings are mixed. A study of segregation and obesity among Hispanic adults using 2000 BRFSS data found segregation was associated higher obesity [20]. However, this study did not examine heterogeneity in this relationship by gender or race. Another study of metropolitan-level segregation and weight status in Hispanics was conducted in Mexican-Americans in the National Health and Nutrition Examination Survey [19]. Hispanic segregation was unassociated with obesity among men, but there was a negative relationship among women. These findings are consistent with the gendered nature of the results we present here, but they are also distinct with respect to the direction and significance of the association among women. Unfortunately a direct comparison of these two studies is difficult since BRFSS does not provide information about country of origin (and thus we cannot assess associations specifically for Mexican-Americans). Nevertheless, these contrasting

findings in Mexican-American women compared to a single broad category of Hispanic women highlight the extent to which health effects of segregation may be expected to differ for different Hispanic subgroups. Given the considerable heterogeneity of the Hispanic population with respect to characteristics like nativity, immigration status, country of origin, and race [22,24], associations between segregation and health are likely dependent on such factors and on the associated opportunities afforded to various Hispanic groups as they assimilate in the U.S.

Our findings for Hispanic women lend some support to the segmented assimilation theory [18] and suggest race may have a persistent influence on segregation and its relationship with health among Hispanics. Previous research shows that, compared to Hispanic Blacks, Hispanic Whites are less segregated from non-Hispanic Whites and more segregated from non-Hispanic Blacks [29]. Thus, Hispanic Whites living in low Hispanic segregation areas may be more likely to reside in predominantly non-Hispanic White neighborhoods. Living in these neighborhoods may be associated with lower BMI through lower levels of concentrated poverty and closer proximity to supermarkets [41,42]. In contrast, Hispanic Blacks living in low Hispanic segregation areas may be more likely to reside in poor quality, predominantly non-Hispanic Black neighborhoods as a result of race-related forces such as housing discrimination and neighbors' hostility [29]. Residence in such areas may be associated with a higher BMI as a result of poorer quality and limited availability of health-promoting social and physical environmental resources (e.g., limited healthy food availability and lower neighborhood safety) [6,41,43]. This explanation is supported by our descriptive findings that Hispanic Blacks living in low Hispanic segregation areas were more likely to live in high non-Hispanic Black segregation areas, while Hispanic Whites living in low Hispanic segregation areas were more likely to live in high non-Hispanic White segregation areas. Unfortunately, because we do not have neighborhood-level information, we cannot ascertain the racial or ethnic composition of the actual neighborhoods where Hispanic Blacks and Whites are residing within these different MMSAs.

In addition to the differential residential opportunities available to Hispanic Blacks and Whites living in low Hispanic segregation areas, living in predominantly Hispanic neighborhoods may also have different health implications for Hispanic Blacks and Whites. For Hispanic Blacks, living in predominantly Hispanic neighborhoods may be associated with lower BMI by protecting them from the stress of exposure to discrimination [44,45] and providing them with better access to healthy foods [14,17]. This is consistent with the ethnic density hypothesis which posits that for minorities, living in communities with a high density of one's own race or ethnic group may be health-promoting due to the presence of strong social

networks and reduced exposure to direct prejudice [46]. This is also supported by several studies among Hispanics (largely Mexican Americans) that have shown that living in a predominantly Hispanic neighborhood is associated with better health including birth outcomes, mortality, and self-rated health [47].

Another key finding of this paper is that race differences in BMI were substantially smaller for those living in highly segregated Hispanic areas than those in less segregated areas. This is similar to findings from other studies that examined race differences among non-Hispanics living in similar environmental conditions. For example, non-Hispanic Blacks and Whites living in an integrated community in Baltimore resemble each other more closely in terms of obesity, diabetes, and hypertension prevalence than do non-Hispanic Blacks and Whites in national samples [2,48,49]. In addition, a previous study on metropolitan-level racial segregation and hypertension showed Black-White differences in hypertension prevalence was smaller for those living in low Black segregation, higher poverty neighborhoods [12]. One notable difference between our findings for Hispanics and these previous studies is that the smaller race differences among non-Hispanics were the result of prevalence among Whites being higher in those more integrated communities, not because prevalence was also lower for Blacks. Nevertheless, these findings underscore the role that contextual factors may play in the emergence of race disparities, even among Hispanics.

It is not clear why segregation was unrelated to BMI among Hispanic women who identified as some other race. The null association may be a reflection of the heterogeneity within that group, both in terms of the reasons that they may self-identify as some other race, and in terms of how they are perceived and treated by others (including other actors in housing markets). Research suggests that with increased assimilation, Hispanics who identified as some other race are less segregated from non-Hispanic Whites than Hispanic Blacks [29]. Therefore, Hispanics who identified as some other race may not experience the same level of housing discrimination, and may have more opportunities for upward mobility and assimilation than Hispanic Blacks, but perhaps less so than Hispanic Whites. Further research is needed in datasets with more detailed information on nativity and country of origin to better understand this finding.

This study is not without limitations. One is that BMI was calculated using self-reported height and weight. Studies show that BMI based on self-report tends to be under-reported [50]. However, there is no evidence of systematic differences in measurement error by race [51]. BRFSS is one of the few studies with sufficient numbers of Hispanic Blacks, which makes using this dataset a strength that outweighs the potential limitations of using self-

reported data. In addition, the large sample size increases the likelihood that the overall patterns of association were still captured despite possible underreporting of BMI. Another limitation is that we did not have neighborhood-level information on participants and only had limited individual-level health behavioral data across the BRFSS survey years. Thus, we were unable to explore the neighborhood- and individual-level pathways through which residential segregation at the metropolitan level may impact BMI.

We also could not distinguish between Hispanic BRFSS participants that were foreign-born or U.S.-born. Previous research suggests that the association between residence in ethnic enclaves and health varies by nativity [21]. The difference in associations by race for women may have been confounded if the immigrant composition for Hispanic Blacks and Whites differed. In the 2000 U.S. Census, Hispanic Blacks were less likely to be foreign-born than Hispanics of other races [52]. We attempted to address this issue by including 'language of interview' as a covariate, which is a commonly used marker of assimilation [36], even though it may not be perfectly correlated with nativity (i.e. not all immigrants are unable to speak English). Nevertheless, future work in this area may benefit from the inclusion of additional measures of assimilation.

Finally, this study is limited by its cross-sectional design. Factors associated with obesity (e.g. health problems due to obesity or desire to live in areas that promote physical activity) may influence selection into metropolitan areas. Although we cannot rule out this selection bias, it is a smaller threat to validity in metropolitan-level segregation studies than in neighborhood-level segregation studies [53]. In addition, residential segregation is hypothesized to act on health across the life course [7]; assessing this relationship at one point in time might not accurately capture the true impact of this process on health.

Conclusions

This is among the first studies to assess the association between metropolitan-level ethnic residential segregation and BMI among Hispanics and to examine heterogeneity by race. Our findings demonstrated racial variation in the association between segregation and mean BMI among Hispanic women. This heterogeneity points to the persistence of race in the U.S. as a driver of structural processes that may limit exposure to health-promoting aspects of residential environments. It also highlights the multiple forms of assimilation that exist among Hispanics and the implications of these assimilation processes for health.

Future work will need to assess the extent that housing discrimination and other forms of blocked mobility limits opportunities for Hispanics in urban areas. Effective solutions to health disparities will need to target the processes

that create segregation and the differential conditions under which individuals live. Better characterization of the roles of racial categorization and related individual- and area-level factors as contributors to variation in disease among Hispanics may facilitate the design of more comprehensive solutions to prevent adverse health outcomes within the fastest growing demographic group in the U.S.

Abbreviations

BMI: Body mass index; MMSA: Metropolitan or micropolitan statistical area; BRFSS: Behavioral risk factor surveillance system.

Competing interests

The authors have no competing interests to declare.

Authors' contributions

Both authors conceived of the study and drafted the manuscript. KNK conducted the analyses. Both authors read and approved the final manuscript.

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