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Racial segregation and maternal smoking during pregnancy: a multilevel analysis using the racial segregation interaction index

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Abstract

Drawing from both the place stratification and ethnic enclave perspectives, we use multilevel modeling to investigate the relationships between women's race/ethnicity (i.e., non-Hispanic white, non-Hispanic black, Asian, and Hispanic) and maternal smoking during pregnancy; and examine if these relationships are moderated by racial segregation in the continental United States. The results show that increased interaction with whites is associated with increased probability of maternal smoking during pregnancy for Asian and Hispanic mothers. In addition, racial segregation moderates the relationships between race/ethnicity and maternal smoking. Specifically, living in a less racially segregated area is related to a lower probability of smoking during pregnancy for black women, but it could double and almost triple the probability of smoking for Asian women and Hispanic women, respectively. Our findings provide empirical evidence for both the place stratification and ethnic enclave perspectives.

Keywords

maternal smoking; pregnancy; racial segregation; race; multilevel models

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Introduction

Maternal smoking during pregnancy is an important public health concern in the United States (US) that has serious implications at both the individual and societal levels. At the individual level, smoking is one of the most significant risk factors for poor pregnancy outcomes, and it has significant and negative implications for both the mother and her child (Bailey & Cole, 2009). Specifically, maternal smoking during pregnancy is associated with an increased risk of pregnancy complications for women (Roelands et al., 2009), and with various undesirable birth outcomes for infants including low birth weight (Agrawal et al., 2010; Castles et al., 1999; Hammoud et al., 2005; Higgins, 2002; Magee et al., 2004; Raatikainen et al., 2007; Wang et al., 1997), placental abruption (Ananth et al., 1999; Higgins, 2002), birth defects (Hwang et al., 1995; Lammer et al., 2005; McDonald et al., 2002), preterm delivery (Cnattingius, 2004; Nkansah-Amankra, 2010), and fetal and infant mortality (Cnattingius, 2004; Kleinman et al., 1988). At the societal level, it is associated with increased economic costs (Adams et al., 2004; Adams & Melvin, 1998; Adams et al., 2002; Castrucci et al., 2006; Halpern-Felsher & Orrell-Valente, 2007; Haviland et al., 2004; Weaver et al., 2008). For example, previous research has estimated that smoking during pregnancy adds over 366 million dollars in neonatal expenditures, or 704 dollars per maternal smoker (1996 dollars) (Centers for Disease Control and Prevention, 2004). Moreover, the additional health care costs of all birth complications caused by maternal smoking during pregnancy are approximately two billion dollars per year (Adams et al., 1997), and the additional cost accumulates significantly with hospital inpatient admissions and early intervention (Miller et al., 2006; Petrou et al., 2005).

Reflecting on the importance of maternal smoking during pregnancy, *Healthy People 2020* identified reducing maternal smoking during pregnancy from 10.4% (2007) to 1.4% by 2020 as one of its objectives (US Department of Health and Human Services, 2011). While maternal smoking during pregnancy is one of the most significant risk factors for poor pregnancy and birth outcomes, it is also one of the most modifiable and preventable (Cnattingius, 2004; Moga & Preda, 2008; Webb et al., 2011); and understanding *both* individual and residential context risk factors for smoking during pregnancy is essential for reaching this goal.

Despite the need to investigate the factors influencing maternal smoking during pregnancy at multiple levels, previous research has predominately focused on the characteristics of women that are associated with an increased likelihood of smoking during pregnancy at the individual level. These maternal characteristics include being from a non-Hispanic white racial background (Mathews, 1998; Stroud et al., 2009), not being married (Flick et al., 2006; Martin et al., 2008; Orr et al., 2005; Pickett et al., 2008; Wakschlag et al., 2003), receiving late prenatal care (Wakschlag et al., 2003; Zimmer & Zimmer, 1998), and being pregnant with a second or higher order infant (Kahn et al., 2002; Martin et al., 2008; Schramm, 1997). In addition, socioeconomically disadvantaged women, that is, women with a low household income (Hunt & Whitman, 2011; Martin et al., 2008; Wakschlag et al., 2003), low educational attainment (Kahn et al., 2002; Martin et al., 2008; Orr et al., 2005; Wakschlag et al., 2003), or living in poverty (Yu et al., 2002) are also more prone to smoke during pregnancy (Pickett et al., 2008). Although there has been a scholarly push to move

beyond the individual level and to consider contextual factors in understanding maternal smoking during pregnancy (Pickett et al., 2002; Sellstrom et al., 2008), studies investigating the contextual level influences on individual maternal smoking during pregnancy behavior have been scant up to date (Gage et al., 2007). In addition, those few previous studies investigating the contextual-level influences on individual maternal smoking during pregnancy behavior have focused on only one or two racial and ethnic groups (e.g., non-Hispanic white and non-Hispanic black) (Bell et al., 2007; Pickett et al., 2002) and limited geographic locations (e.g., a specific state or metropolitan areas) (Pickett et al., 2002).

To add to the maternal health literature, we aim to investigate how contextual-level influences can explain racial and ethnic disparities in maternal smoking during pregnancy in the US by drawing from racial segregation literature. The first goal of this study is to build upon previous studies of maternal smoking during pregnancy by examining how racial segregation is associated with the odds of smoking during pregnancy among non-Hispanic white, non-Hispanic black, non-Hispanic Asian, and Hispanic women (hereafter simply “white, black and Asian”) in the continental US. Expanding from previous studies which have mainly focused on one racial group (Bell et al., 2007; Pickett et al., 2002) or limited geographic locations (Pickett et al., 2002), we aim to provide a comprehensive overview on how racial segregation is associated with the odds of smoking during pregnancy for different racial and ethnic groups in the US. The second goal of this study is to further investigate whether and how racial segregation moderates the relationships between women’s race/ethnicity and maternal smoking during pregnancy.

Racial segregation and smoking during pregnancy

Racial segregation, or the separation of one racial/ethnic group from another (Massey & Denton, 1988), and its effects on health follow two distinctive theoretical foundations: (1) place stratification suggests racial segregation is harmful to the health of minorities, and (2) ethnic enclaves are beneficial for overall well-being. Current research reveals that each theoretical framework does not consistently explain the health outcomes across racial/ethnic minority groups in the US. That is, numerous studies lend support to the place stratification perspective when explaining context-specific health disparities between blacks and whites (Ellen et al., 2000; Osypuk & Acevedo-Garcia, 2008; Subramanian et al., 2005). On the other hand, previous studies have shown that ethnic enclaves provide a buffer against poor health behaviors, and promote healthy behaviors on several health outcomes (Osypuk et al., 2009; Vega et al., 2011) for Hispanics and Asians. We will further elaborate on each theoretical perspective below.

Place stratification perspective

According to the place stratification perspective, individual and institutional discrimination against minority groups encourages racial segregation (Massey & Denton, 1993), and it can be adversely related to individuals’ health (Walton, 2009). Previous studies have found that through a number of interconnected mechanisms, racial segregation is negatively associated with undesirable health outcomes and health-related behaviors (Kramer & Hogue, 2009)

including poor mental health (Mair et al., 2010), poor physical health including obesity (Corral et al., 2012), and inadequate health literacy (Goodman et al., 2012).

One of the interconnected mechanisms through which racial segregation can be negatively associated with individuals' health is through its effects on stress and mental health. High stress and negative mental health outcomes are influenced by several factors. For example, racial segregation is associated with unequal access to educational and employment opportunities among residents in highly segregated areas (Dickerson, 2007; Howell-Moroney, 2005), and constructs social environments with high crime rates (O'Flaherty & Sethi, 2007; Peterson & Krivo, 1993; Velez et al., 2003) and poverty (Acevedo-Garcia & Lochner, 2003; Massey & Denton, 1993). Thus, residents living in such neighborhoods are more likely to experience chronic stress and adverse mental health outcomes (Taylor et al., 1997) and to conduct poor health behaviors, particularly smoking (Stead et al., 2001), to cope with this chronic stress.

Racial segregation can also be associated with individuals' health behaviors due to differential access to various resources in racially segregated areas (Williams & Collins, 2001). For example, previous studies have found that racially segregated areas are more likely to have a higher density of liquor stores and fast food restaurants (Kwate, 2008), and are less likely to have walkable neighborhood amenities (Duncan et al., 2012). Thus, racial segregation is a fundamental cause for creating such physical infrastructure and differential access to various resources (Kwate, 2008).

The place stratification perspective posits that racial segregation is an inherent social means of organizing inequality (Logan, 1978). Logan (1978) argues that spatial stratification evolves and becomes more rigid overtime as individual actors within a community organize and use collective action to maintain their position in society. Thus, disadvantaged communities that lack the ability to effectively mobilize resources to promote community development are more likely to have poor physical infrastructure; and lack of access to health promoting resources, which can, in turn, contribute to deterioration of health among disadvantaged groups.

The place stratification perspective above suggests that black-white segregation in U.S. history has created structural disadvantages and poorly resourced neighborhoods for blacks, who are often forced to be segregated from the dominant racial group (Williams & Collins, 2001). The black-white segregation is a mechanism through which social resources are disproportionately channeled into neighborhoods with high concentrations of white population (Massey & Denton, 1993). Consequently, the blacks are exposed to the environment with many risk factors for smoking, such as job loss and economic hardship. Extending from the place stratification perspective, should the segregation from the dominant racial group be eliminated, the blacks should be able to access the resources that may help to cease smoking, particularly during pregnancy.

It is also important to note that recent studies (Shaw et al., 2010; Bell et al., 2007; Hunt & Whitman, 2011) reported potential benefits that are associated with high level of segregation, such as social cohesion and mutual trust within minority groups (Putnam, 2007;

Laurence, 2011), suggesting that some characteristics of high black-white segregation may be translated into a protective effect on health outcomes/behaviors. However, this emerging knowledge stream does not follow the place stratification perspective that emphasized the social structural disadvantages resulted from segregation. The possible beneficial effects of segregation should be investigated from the social capital or network perspective, which is beyond the scope of this study.

We examine the place stratification perspective discussed above for blacks with a large dataset and aim to better understand the intertwined relationships between race/ethnicity, segregation, and maternal smoking during pregnancy. We will investigate whether and how racial segregation, measured with the interaction index, influences the relationships between women's race/ethnicity (i.e., white, black, Asian, and Hispanic) and smoking during pregnancy.

Ethnic enclave perspective

Since the place stratification perspective is mainly used to understand black-white segregation in the US (Logan et al., 1996), it may not be suitable to understand the racial segregation for Asian-white and Hispanic-white segregation (Walton, 2009). Asians and Hispanics are compositionally different (e.g., larger proportion of foreign-born, heterogeneity within the pan-ethnic identity, etc.), and have different historical contexts and contemporary patterns of racial segregation compared to blacks in the US (Iceland & Nelson, 2008; Iceland & Scopilliti, 2008; Park & Iceland, 2011; Walton, 2009). Therefore, the effect of racial segregation on Asians and Hispanics may be qualitatively different from blacks' experience and it may occur through different interconnected mechanisms; whether we can extend the place stratification perspective to explain the experiences of other minority groups, namely Asians and Hispanics is underexplored.

While relatively few studies extend the place stratification perspective to include other racial and ethnic minority groups, some researchers found that the relationships between racial segregation and health behaviors of Asians and Hispanics are dissimilar to those of blacks. That is, unlike for blacks, racial segregation is positively associated with the health and health behaviors of Asians and Hispanics. Racial segregation appears to be beneficial for the health of Asians and Hispanics in multiple dimensions including mental health (Vega et al., 2011), physical health (Osypuk et al., 2009), access to health care (Gresenz et al., 2009; Osypuk et al., 2009) and birth outcomes (Walton, 2009). That is, Asians and Hispanics living in a racially segregated area are more likely to have fewer depressive symptoms (Vega et al., 2011), and to have better self-reported health and fewer chronic conditions (Osypuk et al., 2009).

This protective association between racial segregation and health of Asians and Hispanics is often attributed to ethnic enclaves, which may provide increased social support and social engagement among family and friends, enhance integration into the community, provide better access to educational and occupational resources, and minimize the exposure to discrimination (Berkman & Glass, 2000; Leclerc et al., 1994; Walton, 2009). In other words, these neighborhoods may provide many social and structural resources due to the well-knit

connections among residents of the same race (Eschbach et al., 2004; Lee & Ferraro, 2007; Walton, 2009).

Despite the overarching salubrious relationship of racial segregation with the health and health behaviors of Asians and Hispanics, there are two important complexities to consider. First, there is considerable variation in how racial segregation is associated with health by nativity status. While the second and later generations generally have better health than first generation immigrants in segregated neighborhoods (Lee & Ferraro, 2007), subsequent generations who have experienced 'downward assimilation' have worse health than immigrants in segregated neighborhoods (Logan et al., 2002; Portes & Zhou, 1993; Walton, 2009). Second, the impact of ethnic enclaves on health depends on the specific health outcomes and racial/ethnic groups of interest. For example, Osypuk and colleagues (2009) have found that living in ethnic enclaves is positively associated with healthy food consumption patterns of Asians and Hispanics, but negatively associated with physical activity among Hispanics.

As for maternal smoking, a recent study by Hunt and Whitman (2011) has demonstrated that there is a strong negative correlation between the proportion of residents in a community who were Hispanic and the proportion of women who smoked while they were pregnant. In addition, there is a negative correlation between the proportion of Asian residents and maternal smoking. Although Hunt and Whitman (2011) do not explicitly focus on racial segregation, their findings imply that racial segregation protects mothers from smoking during pregnancy for Asians and Hispanics. The current study will contribute to the understanding of the relationship between racial segregation and maternal smoking during pregnancy for Asians and Hispanics.

Hypotheses

The existing literature on racial segregation and health suggests that racial segregation may affect maternal smoking during pregnancy behavior differently by racial and ethnic groups. Drawing from both the place stratification perspective and the ethnic enclave perspective, we extend prior work on maternal smoking during pregnancy by investigating how racial segregation is associated with the odds of smoking during pregnancy among white, black, Asian, and Hispanic women in the continental US. We also examine how an individual race group (i.e., women's race/ethnicity) interacts with racial segregation to influence maternal smoking during pregnancy. With this research focus in mind, we test the following hypotheses: (H1) Net of other individual covariates, racial segregation is associated with maternal smoking during pregnancy; (H2) extending from the place stratification perspective and the social disadvantage viewpoint, black women who live in an area with high black-white racial segregation will be more likely to smoke while they are pregnant than their counterparts in an area with low racial segregation; and (H3) following the ethnic enclave perspective, Asian and Hispanic women who live in a more highly Asian-white or Hispanic-white racially segregated area will be less likely to smoke while they are pregnant in contrast with other minority women in less segregated areas.

Methodology

Data

The individual-level data for this study comes from the National Center for Health Statistics 2008 non-public use detailed natality files (National Center for Health Statistics, 2008). This dataset is based on the total population of women who lived in the US and had a live birth during the 2008 calendar year. Smoking during pregnancy is not reported on the birth certificate in California; therefore, women who resided in California were excluded from the analysis. Also, American Indian/Alaskan Native (AIAN) women are excluded from the analysis, because the AIAN population is too small to look at AIAN racial segregation. The tract- and county-level data for the independent variables come from the 2006–2010 American Community Survey 5-year estimates (American Community Survey, 2010).

Measures

Individual-level measures—The dependent variable used in this analysis, *maternal smoking during pregnancy*, is measured as a dichotomous variable where women who smoked during their pregnancy were coded as 1 and women who did not smoke were coded as 0. As for the independent variables, covariates that have been identified from previous research to be significantly associated with maternal smoking during pregnancy (see introduction section) are included in the models. Maternal age at the time of the infant's birth is measured with the continuous variables *age* and *age squared*. For the purpose of interpretation, these two age-related variables are grand centered in the regression analysis (Enders & Tofighi, 2007). Maternal race/ethnicity is measured by a set of dichotomous variables representing the self-reported racial/ethnic groups: *non-Hispanic black*, *non-Hispanic Asian*, and *Hispanic* with *non-Hispanic white* as the reference group. Marital status is measured in this analysis by a dichotomous variable indicating whether the woman was *married* (coded as 1) at the time of the infant's birth or not (coded as 0). Maternal education is measured by a set of dichotomous variables that indicate the woman's highest level of education completed at the time of the infant's birth, which includes *high school/GED*, *some college/associate's degree*, and *bachelor's degree or higher*, with *less than high school* as the reference category.

Prenatal care utilization is measured in this study using the Adequacy of Prenatal Care Utilization Index (APNCU), which is a measure that takes into account both the month prenatal care began and the number of prenatal care visits attended, and it is adjusted for the gestational age of the infant at delivery (Kotelchuck, 1994a, b). The APNCU is measured as a set of dichotomous measures: *inadequate care* (reference category), *intermediate care*, *adequate care*, and *adequate plus care*. Finally, in order to determine if the woman was having her first (coded as 1) or higher order pregnancy (coded as 0), a dichotomous measure *first birth* was included in the models.

County-level measures—Racial segregation is measured in multiple ways in the literature, and different measures illustrate different aspects of racial segregation. For this analysis, we focus on the racial segregation dimension of exposure using the interaction index (${}_xP_y^*$) (Massey & Denton, 1988; Reardon, 2006). This measure was selected because

it compares two subgroups to each other when calculating the racial segregation measure instead of considering one group by itself. In addition, this measure best reflects the theoretical conceptualization outlined in this study (i.e., that there are potentially different mechanisms for different racial/ethnic groups) and captures racial segregation of several minority groups relative to the non-Hispanic white majority. We calculate each index of racial segregation by aggregating up from the tract-level to the county-level. On average, in 2008, a county has 96,773 residents but the variable in population size at the county level is great (min=42 and max=9,862,049). A tract has an average population of 4,222 and the minimum is 1 and the maximum is 37,452.

Racial exposure refers to the possibility of interaction between residents of different races within a county. Indices of exposure measure the extent to which residents come into contact with one another simply by sharing a common residential area. The *interaction index*, a basic measure of residential exposure, measures the extent to which residents of different racial groups (e.g., white-black) are exposed to residents of the opposite race. It has been denoted as ${}_xP_y^*$ and calculated:

$${}_xP_y^* = \sum_{i=1}^n \left| \frac{x_i}{X} * \frac{y_i}{t_i} \right|$$

where x_i , y_i , and t_i are the number of residents who are non-Hispanic black, the number of residents who are non-Hispanic white, and the total population of tract i within a county, respectively. X represents the total number of non-Hispanic black residents in the county. The index varies between 0 and 1 and can be interpreted as the probability that a minority group resident shares an area with a majority group (e.g., non-Hispanic black shares with non-Hispanic white). This analysis includes the following racial segregation indices: *non-Hispanic black:non-Hispanic white (NHB:NHW) interaction index*, *non-Hispanic Asian:non-Hispanic white (NHA:NHW) interaction index*, and *Hispanic:non-Hispanic white (H:NHW) interaction index*. While the index is measured at the county-level by aggregating across tracts within a county, a more fine-grained measure would be ideal, but because of data limitations with the individual-level data, the county is the lowest level of identifiable geography available.

The discussions above demonstrated that the study design aims to cover the whole population (i.e., women who gave a birth in 2008 and lived in the US) and to link individual data to the counties where they lived. While it is a cross-section design, the data sources are all maintained by the Federal agencies, which, to some extent, guarantee the data quality and reliability. The limitations of the study design will be discussed later in this paper.

Analytic approach

In order to test the three hypotheses, we applied the logistic multilevel models to the data described above. Following the common practice (Raudenbush and Bryk, 2002), we first conducted a null model without any explanatory covariates, which is equivalent to an ANOVA model and allows us to justify the use of this multilevel modeling approach. The null models indicated that a multilevel modeling approach was necessary as indicated by the

intraclass correlation coefficients (ICC) (Merlo et al., 2006; Merlo et al., 2005). The ICCs revealed considerable clustering of individual maternal smoking during pregnancy within counties with 14 percent of the total individual differences in maternal smoking during pregnancy occurring at the county-level, which may be attributable to contextual county factors or to the different composition of counties (Merlo et al., 2005).

The next step was to include, both the individual- and county-level covariates in the analysis, generating results that can test our hypotheses. The final model can be expressed as below:

$$\eta_{ij} = \log \left(\frac{\phi_{ij}}{1 - \phi_{ij}} \right) = \gamma_{00} + u_{0j} + \sum \gamma_{0l} w_{lj} + \sum \beta_{kj} x_{ijk}$$

where

η_{ij} is the log odds of smoking for the i th individual in the j th county

ϕ_{ij} is the odds of smoking for the i th individual in the j th county

γ_{00} is the intercept

u_{0j} is the random effect following a normal distribution with a mean of 0 and a county-level variance

γ_{0l} is the direct effect of county-level covariate l

w_{lj} is the county-level covariate l of j th county

β_{kj} is the fixed effect of individual covariate k

x_{ijk} is the covariate k of individual i at county j

This particular model will allow us to understand if racial segregation is associated with maternal smoking during pregnancy, net of other explanatory covariates. The county-level random errors could be understood as the level-2 (i.e., county) variances that are not explained by the county-level covariates.

To examine the moderating association of racial segregation between race and maternal smoking, the last model considers the cross-level interaction between maternal race/ethnicity and racial segregation. More specifically, we examine if the relationship between maternal race/ethnicity and maternal smoking varies by the level of racial segregation in a county. For example, the effect of Black can be specified to interact with black-white segregation, the formula for which is expressed below:

$$\beta_{black,j} = \gamma_{10} + \sum \gamma_{black,segregation} w_{segregation,j} + u_{1,j}$$

where $\gamma_{black,segregation}$ is the interaction relationship between black and racial segregation on maternal smoking. The formula above can be extended to other racial groups and permits us to test the third hypothesis. We used HLM 6 (Raudenbush et al., 2004) to conduct the analysis.

Results

Descriptive statistics

The descriptive statistics for each of the measures included in the analysis are presented in Table 1 for all women as well as for each racial/ethnic group. As shown, overall 11 percent of women smoked during their pregnancy. However, this percentage varies greatly by race/ethnicity. Maternal smoking during pregnancy is highest among non-Hispanic white women (15 percent), followed by non-Hispanic black women (9 percent), Hispanic women (3 percent), and non-Hispanic Asian women (2 percent). The racial segregation interaction index was approximately 0.15 for each of the indices. This means that, on average, the probability that a minority group resident shares an area with a majority group (e.g., non-Hispanic black shares with non-Hispanic white) is 0.15.

Multilevel logistic regression results

The results of the multilevel logistic regression models predicting the odds of maternal smoking during pregnancy are displayed in Table 2. Four separate models are presented for the null and full models. The first models include the individuals who live in counties where the non-Hispanic black:non-Hispanic white (NHB:NHW) interaction index can be measured, the second models include women who live in counties where the non-Hispanic Asian:non-Hispanic white (NHA:NHW) interaction index can be measured, the third models include the women from counties where the Hispanic:non-Hispanic white (H:NHW) interaction index can be measured, and the fourth models include women who live in the counties where all three interaction indices can be measured. The interaction indices cannot be measured for those counties that do not have any of the minority group residing in the county. The coefficients for the individual-level parameter estimates are stable across the models, so the results from the final model (Model VIII) are discussed here. The individual-level characteristic results show that, compared to the mean age of mothers, a one year increase in maternal age is associated with roughly 28 percent increase in the odds of smoking ($1.287^{(1)} \times 0.996^{(1)} = 1.282$). However, for a mother of age 30, the odds of smoking would be raised by almost 95 percent ($1.287^{(2.75)} \times 0.996^{(2.75)} = 1.942$) in contrast to a mother with the average age, assuming all other variables are the same. Assuming that there is no segregation at all, the odds of smoking during pregnancy for black women was 32% (OR: 0.32; 95% CI: 0.315–0.324) of the odds of smoking for white women. Similarly, Asian and Hispanic women had the odds of smoking that were 20% (OR: 0.20; 95% CI: 0.191–0.206) and 9% (OR: 0.095; 95% CI: 0.093–0.091) of the odds of smoking for white women, respectively. Married women had the odds of smoking that was only 33% (OR: 0.33; 95% CI: 0.327–0.333) of the odds for women who were not married when giving a birth.

The odds of smoking during pregnancy was lower among women with higher levels of education or had better prenatal care utilization than their counterparts with less than a high school degree or had inadequate prenatal care. Women who were giving their first birth had the odds of smoking that was roughly 72% (OR: 0.719; 95% CI: 0.713–0.726) of the odds of smoking for women who were not giving the first birth. As for racial segregation, the results suggest that racial segregation moderates the relationship between race/ethnicity and

smoking during-pregnancy. This is the case when each of the racial segregation measures are tested independently (Models V–VIII) and simultaneously (Model VIII). To better interpret the interaction terms between race/ethnicity and segregation, the predicted probability of smoking for each race/ethnicity based on Model VIII was calculated (Norton et al., 2004) and shown in Figure 1. The y-axis represents the predicted probability of maternal smoking and the x-axis shows the possible values of the interaction index with 0 being the most segregated and 1 being the least segregated. The line with square markers indicates the predicted probability of maternal smoking for blacks, the line with triangle markers represents Asians, and the line with circle markers demonstrates the predicted probability for Hispanics

The predicted probability for black women decreases as the level of segregation from the strongest segregation (index =0) to no segregation (index =1). More specifically, the predicted probability for black women living in the most segregated county (index = 0) was slightly over 0.3, whereas the predicted probability of smoking during pregnancy became lower than 0.25 when the interaction index was equal to 1 (the least segregated). The difference in the probability of maternal smoking during pregnancy associated with residential segregation was roughly 0.08 ($0.311 - 0.235 = 0.076$; detailed numbers are available upon request), which is the moderation introduced by racial segregation. In other words, for black women, living in a county where blacks are more segregated from whites is associated with higher probability of maternal smoking during pregnancy.

For Asian women, the predicted probability demonstrated an upward trend from the most segregated county (index =0 and the probability is 0.218) to the least segregated county (index =1 and the probability is 0.452). The difference in the probability is 0.234, which is more than double of the probability of smoking when living in a county with an interaction index of 0. That being said, *ceteris paribus*, in terms of maternal smoking behavior, Asian women seemed to benefit more from living in a county where Asians are segregated from whites than in a county where these two racial groups are integrated.

The pattern for Hispanic women in Figure 1 is similar to that for Asian women and the probability was almost tripled from the most to the least segregated area. Holding all other covariates the same, the probability of maternal smoking was 0.118 when the interaction index is equal to 0, but the probability became 0.292 when the interaction index is 1. The moderation introduced by the interaction between race/ethnicity and segregation was 0.174 and this increase in the probability of maternal smoking suggested that living in a Hispanic-White segregated community could be beneficial for Hispanic mothers, which confirms our hypothesis.

Figure 1 also suggested that the probability of maternal smoking is comparable between black and Asian women when the interaction index is approximately 0.35, after which the probability of maternal smoking for Asian mothers was higher than that for black mothers. The probability of maternal smoking for Hispanic mothers remained the lowest until the interaction index reaches 0.8, where the probability of maternal smoking is the same for black and Hispanic mothers.

Discussion and Conclusion

Racial segregation remains a prominent feature in American society (Massey & Denton, 1993), and segregation is a fundamental cause of disease, making it a crucial issue for public health (Link & Phelan, 1995; Williams & Collins, 2001). With the rapid increase in immigration and population compositional changes, understanding how racial segregation affects the health of different racial and ethnic groups is imperative (Williams & Sternthal, 2010). The current study investigates whether and how racial segregation is associated with maternal smoking during pregnancy, and whether and how the relationships between women's race/ethnicity and maternal smoking during pregnancy are moderated by racial segregation in the US. It expands the previous literature by moving beyond the typical approach that mainly emphasized individual-level factors for maternal smoking during pregnancy. In addition, it builds upon the limited literature investigating the contextual-level factors for maternal smoking during pregnancy by including women from various racial and ethnic backgrounds, instead of focusing on women who identify with one or two racial and ethnic backgrounds (Bell et al., 2007; Shaw et al., 2010), and by including most counties in the US rather than just select metropolitan areas (Bell et al., 2007; Hunt & Whitman, 2011; Shaw et al., 2010).

We revisit our hypotheses based on the findings in the previous section. We first hypothesized that racial segregation is associated with maternal smoking even after considering individual covariates. Our results support this hypothesis as they show that the interaction indices are associated with the odds of maternal smoking during pregnancy (see Table 2). In other words, more interactions with non-Hispanic whites could be translated into a higher probability of maternal smoking during pregnancy, particularly for non-Hispanic Asians and Hispanics. Our second hypothesis stated that living in a less segregated area could be translated into a lower probability of smoking during pregnancy for blacks. The predicted probability in Figure 1 provides evidence to support the place stratification perspective. Finally, our third hypothesis based on the ethnic enclave perspective was supported. Explicitly, the beneficial effects of racial segregation were found for Asians and Hispanics and the mechanism seemed to go through the interaction between race/ethnicity and county-level racial segregation (see Figure 1). As the focus of this study is to expand the literature by exploring the contextual factors for maternal smoking during pregnancy, the discussion on the individual-level covariates was limited. However, we would like to note that our individual-level findings are consistent with a recent study on maternal smoking during pregnancy (Shoff & Yang, 2013).

Although understanding the specific mechanisms by which racial segregation differentially affects maternal smoking across racial and ethnic groups is beyond the scope of this study, there are several potential explanations. First, these findings may reflect the different composition and social histories of racial segregation for non-Hispanic black women compared with Asian and Hispanic women. Compositionally, Asian and Hispanic women are more likely to be immigrants, and immigrants are more likely to have better self-reported health and fewer chronic disorders (Acevedo-Garcia et al., 2010; Jasso et al., 2004). Future studies should investigate whether immigrant-related characteristics such as nativity (e.g., immigrant selection), acculturation, and contexts of reception account for differential

relationships between racial segregation and maternal smoking during pregnancy. Second, racial segregation may differentially affect maternal smoking across racial and ethnic groups through stress/mental health and opportunity structures. That is, racial and ethnic minorities living outside of ethnic enclaves may be exposed to a higher level of discrimination and other factors that affect individuals' stress which may be associated with their smoking behavior. In addition, there may be less culture-specific opportunity structure that prevents individuals from smoking during pregnancy. Future research should investigate whether the relationship between racial segregation and maternal smoking is mediated by these other factors. For example, this study has found that the relationship between segregation and maternal smoking is mediated by socioeconomic status of a neighborhood (results not shown but available upon request). Other contextual factors, such as social cohesion and mutual trust within minority groups, may be considered to further untangle the association of segregation with maternal smoking behavior.

Furthermore, Asian and Hispanic women may have different social histories and current context of racial segregation compared with non-Hispanic black women. That is, while active discrimination by whites against blacks creates and perpetuates racial segregation, (i.e., place stratification), racial segregation for Asians and Hispanics may be etiologically different. Racial segregation for Asian and Hispanic women may reflect greater exposure to immigrant communities that foster healthier lifestyles and behaviors via social support (Berkman & Glass, 2000). In addition, a more racially integrated residential context (e.g., non-Hispanic white residential context) may expose Asian and Hispanic women to social norms with a higher smoking prevalence; higher tobacco use in these contexts may inadvertently heighten access to these products compared with ethnic enclaves where both the demand and supply for tobacco products may be lower (Stead et al., 2001).

While this study contributes to understanding the influences of racial segregation on maternal smoking behaviors across racial and ethnic minorities, it has certain limitations. First, the exclusion of birth records from California may present bias, since racial segregation in California is relatively high (Michigan Population Studies Center, 2013). This may underestimate the true association between racial segregation on maternal smoking during pregnancy, especially for the minority groups. Second, we measure racial segregation by aggregating up from the tract- to the county-level. Counties are not the ideal unit to measure racial segregation, because they may not capture the interaction of racial minorities with the majority group at the neighborhood-level. Nevertheless, counties represent meaningful political boundaries, where public health services can be administered more efficiently, and they are more identifiable than smaller units such as census tracts or block groups (Allen, 2001). Third, we use a single dimension of residential segregation, interaction between groups. While other health studies have found similar effects for multiple segregation indices (Sparks et al., 2013), our results could change if an alternative segregation index was chosen. Fourth, we only capture the behaviors of women at one point in time, so we are unable to make causal inferences about the relationship between racial segregation and maternal smoking across time or space. Finally, maternal smoking is self-reported. If women perceive there is a stigma associated with reporting poor health behaviors during pregnancy, smoking prevalence may be underestimated. For example, a recent study has found that there are disproportionate underreporting for women who are

college-educated, married, older than 30 years old, employed full-time, and planning to breastfeed (Land et al., 2012). Although there is no population-based empirical study that has investigated the racial and ethnic differences in underreporting in maternal smoking during pregnancy in particular, given the strong evidence that there are significant reporting differences of self-reported health by race and ethnicity (Dowd & Todd, 2011); we suspect that there may be systematic differences in underreporting of maternal smoking during pregnancy by race and ethnicity.

Despite these limitations, these findings have important implications for both policymaking and future research. First, the differential associations of racial segregation and maternal smoking during pregnancy across various racial and ethnic groups suggest that public policy aiming to reduce maternal smoking during pregnancy may be more efficient and effective when strategies specific to racial/ethnic groups are developed and implemented. Second, future research should aim to investigate the specific mechanisms that explain why racial segregation affects maternal smoking during pregnancy behaviors differently for various racial and ethnic groups. Specifically, future research should investigate the mechanisms by which racial integration has deleterious effects on maternal smoking for Asian and Hispanic women and the potential benefits for blacks (Shaw et al., 2011). This is imperative given the changing racial and ethnic landscape in the US, and there is some evidence that subsequent generations adopt the poor health behaviors of the majority group as they assimilate (Portes & Zhou, 1993). Understanding the specific mechanisms by which racial segregation affects maternal smoking during pregnancy behaviors will help to provide more comprehensive understanding of maternal smoking during pregnancy.

In sum, as mentioned earlier, maternal smoking during pregnancy can have significant and negative implications for both the mother and her child (Bailey & Cole, 2009), and public policy reflects the importance (e.g., *Healthy People 2020*) (US Department of Health and Human Services, 2011). In order to reduce maternal smoking during pregnancy in the US, it is imperative to identify the determinants and specific mechanisms. This study demonstrates that county-level racial segregation plays an important role in understanding the relationship between race/ethnicity and maternal smoking during pregnancy. Our empirical findings indicate that both the place stratification perspective and the ethnic enclave perspective are valuable frameworks for understanding how racial segregation affects maternal smoking during pregnancy, and incorporating contextual factors beyond individual characteristics may help address the racial/ethnic disparity in maternal smoking during pregnancy.

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Highlights

- The race/ethnicity-smoking association varied by racial segregation.
- Low segregation is related to low probabilities of smoking for black mothers.
- High segregation lowers probabilities of smoking for non-black minority women.
- Place stratification and ethnic enclave perspectives explain the racial difference.

Figure 1.
Predicted probability of smoking by race/ethnicity across the interaction index values (based on Model VIII)

Table 1

Descriptive statistics of variables at both individual-level and county-level.

Variables	All	NH-White	NH-Black	NH-Asian	Hispanic
Individual-level measures (N=3,450,455)	100%	59%	16%	4%	21%
Smokes (percent)	11	15	9	2	3
Maternal age (years)					
Age	27.25	27.86	25.51	30.21	26.23
Age squared	779.56	811.57	688.89	940.26	725.58
Marital status (percent)					
Married	59	71	27	86	47
Maternal education (percent)					
Less than high school (reference)	20	11	23	11	45
High school/GED	28	26	36	17	29
Some college/Associate's degree	25	28	28	18	17
Bachelor's degree or higher	27	35	13	54	9
Prenatal Care Utilization (percent)					
Inadequate care (reference)	17	11	24	15	25
Intermediate care	12	12	12	13	14
Adequate care	40	44	33	43	35
Adequate plus care	31	33	31	29	26
Parity (percent)					
First birth	41	43	40	47	36
County-level measures (N=2,556)					
Racial segregation					
NHB:NHW interaction index	0.14		0.17		
NHA:NHW interaction index	0.15			0.17	
H:NHW interaction index	0.15				0.20

Table 2

Multilevel logistic regression models predicting maternal smoking during pregnancy.

Null Models				
Individual-level measures	Model I ^a	Model II ^b	Model III ^c	Model IV ^d
Intercept	0.212 *** (0.206, 0.218)	0.210 *** (0.204, 0.217)	0.211 *** (0.205, 0.217)	0.210 *** (0.204, 0.217)
<i>Variance Components</i>				
Variance of intercept ^e	0.519 ***	0.519 ***	0.513 ***	0.527 ***
<i>Model Diagnostics</i>				
Intraclass correlation coefficient (ICC)	0.136	0.136	0.135	0.138
Median odds ratio (MOR)	1.988	1.988	1.980	1.998
Full Models				
Individual-level measures	Model V ^a	Model VI ^b	Model VII ^c	Model VIII ^d
Intercept	1.436 *** (1.393, 1.481)	1.445 *** (1.401, 1.491)	1.463 *** (1.420, 1.507)	1.411 *** (1.366, 1.458)
Maternal age				
Age (centered)	1.287 *** (1.279, 1.295)	1.286 *** (1.278, 1.294)	1.287 *** (1.279, 1.294)	1.287 *** (1.279, 1.294)
Age squared (centered)	0.996 *** (0.996, 0.996)	0.996 *** (0.996, 0.996)	0.996 *** (0.996, 0.996)	0.996 *** (0.996, 0.996)
Race/Ethnicity (Non-Hispanic White=reference)				
Non-Hispanic Black	0.320 *** (0.316, 0.325)	0.314 *** (0.310, 0.318)	0.313 *** (0.309, 0.317)	0.320 *** (0.315, 0.324)
Non-Hispanic Asian	0.204 *** (0.197, 0.211)	0.198 *** (0.191, 0.205)	0.204 *** (0.197, 0.211)	0.198 *** (0.191, 0.206)
Hispanic	0.097 *** (0.096, 0.099)	0.097 *** (0.096, 0.099)	0.095 *** (0.094, 0.097)	0.095 *** (0.093, 0.096)
Marital status				
Married	0.332 *** (0.329, 0.335)	0.331 *** (0.328, 0.334)	0.332 *** (0.329, 0.335)	0.330 *** (0.327, 0.333)
Maternal education (Less than High School=reference)				
High school/GED	0.620 *** (0.614, 0.627)	0.621 *** (0.615, 0.627)	0.621 *** (0.615, 0.627)	0.620 *** (0.614, 0.627)
Some college/Associate's degree	0.339 *** (0.335, 0.343)	0.339 *** (0.335, 0.343)	0.339 *** (0.335, 0.343)	0.339 *** (0.335, 0.343)
Bachelor's degree or higher	0.062 *** (0.061, 0.063)	0.062 *** (0.061, 0.063)	0.062 *** (0.061, 0.063)	0.062 *** (0.061, 0.063)
Prenatal Care Utilization (Inadequate care=reference)				
Intermediate care	0.783 *** (0.772, 0.794)	0.783 *** (0.772, 0.794)	0.784 *** (0.773, 0.795)	0.783 *** (0.772, 0.794)

Adequate care	0.686*** (0.678, 0.693)	0.686*** (0.678, 0.693)	0.687*** (0.680, 0.695)	0.685*** (0.677, 0.693)
Adequate plus care	0.736*** (0.728, 0.744)	0.736*** (0.728, 0.745)	0.737*** (0.729, 0.746)	0.735*** (0.727, 0.744)
Parity				
First birth	0.719*** (0.713, 0.726)	0.720*** (0.713, 0.726)	0.719*** (0.713, 0.726)	0.719*** (0.713, 0.726)
County-level measures				
<i>Direct Associations</i>				
Racial segregation				
NHB:NHW interaction index	2.025*** (1.776, 2.308)			1.684---- (0.880, 3.222)
NHA:NHW interaction index		1.837*** (1.614, 2.091)		1.044---- (0.599, 1.821)
H:NHW interaction index			1.575*** (1.411, 1.758)	1.361---- (0.651, 2.845)
<i>Moderating Associations</i>				
Non-Hispanic Black by NHB:NHW interaction index	0.357*** (0.264, 0.482)			0.405*** (0.292, 0.561)
Non-Hispanic Asian by NHA:NHW interaction index		3.238** (1.515, 6.921)		2.829* (1.223, 6.542)
Hispanic by H:NHW interaction index			1.990*** (1.605, 2.468)	2.268*** (1.737, 2.961)
<i>Variance Components</i>				
Variance of intercept ^e	0.244***	0.248***	0.246***	0.246***
<i>Model Diagnostics</i>				
Intraclass correlation coefficient (ICC)	0.069	0.070	0.070	0.069
Median odds ratio (MOR)	1.601	1.608	1.608	1.604
<i>Sample sizes^f</i>				
Individual-level N	N=3,481,143	N=3,462,114	N=3,495,172	N=3,450,455
County-level N	N=2,809	N=2,704	N=3,014	N=2,556

^aThis model includes all women who live in counties where the non-Hispanic black:non-Hispanic white (NHB:NHW) interaction index can be measured.

^bThis model includes all women who live in counties where the non-Hispanic Asian:non-Hispanic white (NHA:NHW) interaction index can be measured.

^cThis model includes all women who live in counties where the Hispanic:non-Hispanic white (H:NHW) interaction index can be measured.

^dThis model includes all women who live in counties where all three interaction indices can be measured.

^eThis number refers to the variance of the random intercept.

^fThe sample sizes of women and counties vary across the models because the interaction indices can only be constructed for those counties that inhabit individuals of both the minority race/ethnicity examined and white individuals. Only women who live in counties where the interaction index being examined can be measured are included in the model.

Notes: Results are reported in odds ratios;

*
 p 0.05;

**
 p 0.01;

 p 0.001