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Publication Date

2023-10-01

DOI

10.1016/j.socscimed.2023.116196

Peer reviewed

HHS Public Access

Author manuscript

Soc Sci Med. Author manuscript; available in PMC 2024 March 22.

Published in final edited form as:

Soc Sci Med. 2023 October ; 334: 116196. doi:10.1016/j.socscimed.2023.116196.

Neighborhood gentrification, displacement, and severe maternal morbidity in California

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Abstract

Gentrification, a racialized and profit-driven process in which historically disinvested neighborhoods experience an influx of development that contributes to the improvement of physical amenities, increasing housing costs, and the dispossession and displacement of existing communities, may influence the risk of severe maternal morbidity (SMM). Leveraging a racially diverse population-based sample of all live hospital births in California between 2006 and 2017, we examined associations between neighborhood-level gentrification and SMM. SMM was defined as having one of 21 procedures and diagnoses, as described in the SMM index developed by Centers for Disease Control and Prevention. We compared three gentrification measures to determine which operationalization best captures aspects of gentrification most salient to SMM:

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Ethics

Study protocols were approved by the California Committee for the Protection of Human Subjects and the Institutional Review Boards of Stanford University and University of California, Berkeley (Protocol number: 17-04-2932).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2023.116196.

Freeman, Landis 3-D, and Urban Displacement Project Gentrification and Displacement Typology. Descriptive analysis assessed bivariate associations between gentrification and birthing people's characteristics. Overall and race and ethnicity-stratified mixed-effects logistic models assessed associations between gentrification and SMM, adjusting for individual sociodemographic and pregnancy factors while accounting for clustering by census tract. The study sample included 5,256,905 births, with 72,718 cases of SMM (1.4%). The percentage of individuals living in a gentrifying neighborhood ranged from 5.7% to 11.7% across exposure assessment methods. Net of individual and pregnancy-related factors, neighborhood-level gentrification, as measured by the Freeman method, was protective against SMM (OR = 0.89, 95% CI: 0.86–0.93); in comparison, gentrification, as measured by the Gentrification and Displacement Typology, was associated with greater risk of SMM (OR = 1.18, 95% CI: 1.14–1.23). These associations were significant among non-Hispanic White, non-Hispanic Black, and Hispanic individuals. Findings demonstrate that gentrification plays a role in shaping the risk of SMM among birthing people in California. Differences in how gentrification is conceptualized and measured, such as an emphasis on housing affordability compared to a broader characterization of gentrification's multiple aspects, may explain the heterogeneity in the directions of observed associations.

Keywords

Gentrification; Neighborhood and health; Severe maternal morbidity; Racial and ethnic health equity

1. Introduction

The United States is experiencing an alarmingly high rate of pregnancy-related deaths. There are substantial and persistent racial and ethnic inequities in pregnancy-related mortality, with Black and Indigenous birthing people experiencing 2 to 3 times the rate of pregnancy-related mortality compared to their White counterparts (Joseph et al., 2021; Petersen, 2019). Although pregnancy-related death has traditionally been used as the sentinel event to understand the health of pregnant people, severe maternal morbidity (SMM), defined as unexpected and life-threatening health complications related to pregnancy or delivery, occurs more frequently and can be effectively investigated to improve pregnancy outcomes (Centers for Disease Control and Prevention, 2020; Say et al., 2009). Rates of SMM have been increasing in the last decade and demonstrate similar patterns of racial and ethnic inequities, with the highest rates among Black and Indigenous populations; rates among Asian and Latinx birthing people are also elevated, compared to White birthing people (Admon et al., 2018; Centers for Disease Control and Prevention, 2020; Creanga et al., 2014; Kozhimannil et al., 2020; Leonard et al., 2019). Existing studies investigating factors contributing to increases in SMM and SMM racial and ethnic inequities have documented the influence of individual-level factors, including clinical and socioeconomic factors, and hospital-level factors, such as quality of care (Admon et al., 2018; Creanga et al., 2014; Gray et al., 2012; Howell, 2018; Howell et al., 2016a, 2016b, 2017; Leonard et al., 2019; Lindquist et al., 2013; Mujahid et al., 2020). However, these factors do not fully explain racial and ethnic inequities in SMM, illuminating the urgency to address more social-contextual factors, such as the neighborhood environment and its changes.

Neighborhood context, encompassing the social environment, physical characteristics, and community-level resources, has been documented to be a profound determinant of health, including perinatal outcomes (e.g. preterm birth) and health behaviors during pregnancy (Culhane and Elo, 2005; Headen et al., 2019, 2019, 2019; Laraia et al., 2007; Metcalfe et al., 2011; Ncube et al., 2016; Vinikoor-Imler et al., 2011; Vos et al., 2014). While the majority of extant studies examining neighborhood environment and SMM have been limited in scope and measurement, using income measures at the ZIP code level as an adjustment covariate, recent studies have begun to document the impact of contemporary and historical neighborhood-level deprivation (Creanga et al., 2014; Friedman et al., 2016; Friedman et al., 2016; Gao et al., 2022; Janevic et al., 2020; Mujahid et al., 2023; Oud and Watkins, 2015). Neighborhood conditions can also undergo rapid changes due to gentrification, a racialized and profit-driven process in which historically disinvested neighborhoods experience private sector-led and government-subsidized development, resulting in the improvement of physical infrastructure but displacement of long-term residents who are more likely to be a part of marginalized groups (Causa Justa Just Cause, 2015; Rucks-Ahidiana, 2021b; N. Smith, 1998). Gentrification may improve the neighborhood physical environment, which in turn can bolster amenities and resources that support healthy diet, physical activity, and access to healthcare before or during pregnancy, thereby reducing SMM risk for the residents who can access the new amenities (Howell, 2018; Laraia et al., 2007; Mujahid et al., 2019). On the other hand, gentrification can destabilize the social environment through displacement of residents and dissipation of community resources, resulting in elevated risk of SMM due to increased psychosocial stress in the face of the rising cost of living and loss of social support or capital, as well as disrupted access to healthcare as a result of displacement (Mujahid et al., 2019; Schnake-Mahl et al., 2020). Gentrification, and more broadly neighborhood socioeconomic changes, has been examined in relation to infant outcomes and SMM risk factors such as health behavior and chronic diseases, but its influence on pregnancy-related outcomes such as mortality and morbidity has been understudied (English et al., 2003; Huynh and Maroko, 2014; Schnake-Mahl et al., 2020).

The effects of gentrification on health may vary across racial and ethnic groups. While much of the existing literature has defined gentrification in terms of economic changes, the fact that gentrification occurs in disinvested and historically segregated neighborhoods requires this process be understood within historical context (Fallon, 2021). Specifically, under structural racism and racial capitalism, resources have been distributed unequally across neighborhoods along racial and class lines (Almaguer, 2008; Gilmore, 2002; Rucks-Ahidiana, 2021b). In the post-World War II U.S., racially discriminatory policies and programs in housing, education, healthcare, and employment have produced persistent patterns of racial segregation, accompanied by White flight to the suburbs and structural deprivation in neighborhoods where Black and other racially marginalized people live (Fullilove, 2001; Massey and Denton, 1998; Rothstein, 2017). Racial segregation and housing discrimination prevented Black families from accessing financing to purchase home and accumulating generational wealth, thus increasing their vulnerability to the rising cost of living associated with gentrification (Oliver and Shapiro, 2013). Segregated neighborhoods also faced upheaval and displacement that occurred as a result of federal programs such

as urban renewal, slum clearance, and the Highway Act of 1956 (Avila, 2014; Estrada, 2005; Fullilove and Wallace, 2011). For example, 75% of the one million people who were displaced in urban renewal projects were people of color (Fullilove and Wallace, 2011). These processes laid the foundation for the unequal social and material conditions across communities that predicate disinvested neighborhoods' higher chance of experiencing gentrification and marginalized groups' vulnerability to displacement. On the other hand, disinvested neighborhoods with a high proportion of Black and Latinx residents may be less likely to experience reinvestment, due to racism in residential preferences and development practices, as well as systemic devaluation of Black neighborhoods (Hwang, 2015; Hwang and Sampson, 2014; Rucks-Ahidiana, 2021b). Lastly, gentrification may simultaneously benefit high-income White residents who can more easily access the improved amenities and harm working class racially marginalized residents who are more vulnerable to housing instability or rely on disintegrating community support (Mujahid et al., 2019; Wyly and Hammel, 2004). Rich theoretical and historical research documents how racially marginalized populations endured these material realities, yet relatively scant epidemiologic research examines how gentrification's health impact may be different for communities that have historically experienced sequential stages of neighborhood changes and upheaval. Thus, studies are needed to understand potential variations in the impact of gentrification across racial and ethnic groups.

In the gentrification and health literature, there is little consensus on the measures used to operationalize gentrification (Schnake-Mahl et al., 2020; G. S. Smith et al., 2020). Measures of gentrification in existing health studies usually utilized area-level socioeconomic variables characterizing neighborhood housing, education, and income derived from the census, and measured changes in these characteristics over a pre-determined time period (Freeman, 2005; Huynh and Maroko, 2014; Landis, 2015). Other measures have focused on specific aspects of gentrification, such as housing affordability, using rental pricing and home sale data (Chapple and Zuk, 2016; Urban Displacement Project, 2020; Zuk, 2015). A study in San Francisco compared three exposure assessment methods and found that whether tracts were identified as gentrifying varied substantially across the three methods (Mujahid et al., 2019). Studies are needed to investigate which operationalization best captures aspects of gentrification that are especially salient for SMM, and more broadly, pregnancy-related mortality and morbidity.

We set out to examine associations between neighborhood gentrification and SMM among neighborhood residents, leveraging a population-based cohort of births in California during 2006–2017. Gentrification was measured using three methodologies: Freeman—a measure of neighborhood socioeconomic changes commonly used in epidemiologic literature, Landis 3-D—a simplified measure utilizing an income indicator, and Urban Displacement Project (UDP) Displacement and Gentrification Typology—a measure assessing housing affordability as a key feature of gentrification (Freeman, 2005; Landis, 2015; Zuk, 2015). We compared results across exposure assessment methods. To assess whether the influence of gentrification is differential among racially marginalized groups, we assessed effect measure modification by race and ethnicity, then estimated associations between gentrification and SMM in the overall population and within each racial and ethnic group using stratified analysis. This approach positioned race and ethnicity as

a marker for differential exposure and experiences of social marginalization (Jones, 2001). We hypothesized that gentrification would be associated with SMM in the overall study sample, and the magnitude of association would be more pronounced using Freeman and Displacement and Gentrification Typology assessment methods, which more comprehensively characterized multiple dimensions of gentrification. Based on the history of neighborhood formation under the influence of structural racism and capitalism, as well as evidence from prior epidemiologic studies, we hypothesized that the association between gentrification and SMM would be stronger among racial and ethnic groups that have experienced structural marginalization. (Huynh and Maroko, 2014; Schnake-Mahl et al., 2020).

2. Note on language

In this paper, we use gender-inclusive language (e.g., birthing people) in recognition that people of all gender identities, including cis-gender, transgender, and non-binary, experience pregnancy and give birth.

3. Methods

3.1. Study population

Using data from the Department of Health Care Access and Information, our study population leveraged a state-wide population-based sample of all live births that occurred in California hospitals between 2006 and 2017. The datasets linked birth certificates with hospital discharge records (pregnancy through 9 months postpartum), which included records using the International Classification of Diseases (ICD) Clinical Modification 9th and 10th Revision codes of procedures and diagnoses. We linked the birth cohort files to the birthing person's geocoded residential address at infant birth date. Addresses were then geocoded to link to census tract identifiers to enable linkage to neighborhood level exposure variables.

From a total sample of 5,928,329 births, we excluded births if they were missing or had implausible gestational age (<20 weeks or > 45 weeks), unable to be linked to a census tract, missing complete exposure information, or missing any covariate information. We also excluded birthing people who did not report Hispanic ethnicity and whose race was self-reported as "Other" due to the sample size being too small for stratified models. For non-singleton deliveries, we included the first birth. The final analytic sample included 5,256,905 births, or 88.7% of the total sample (Supplemental Fig. 1). Compared to those in the analytic sample, excluded individuals were more likely to be White or American Indian/Alaskan Native, uninsured or have "other" insurance, or have a non-singleton birth. Study protocols were approved by the California Committee for the Protection of Human Subjects and the Institutional Review Boards of Stanford University and University of California, Berkeley (Protocol number: 17-04-2932).

3.2. Study outcome

SMM from delivery hospitalization through 42 days postpartum was defined using a composite index developed by the Centers for Disease Control and Prevention. This index

has been validated using California data and for use with administrative and population surveillance data (Centers for Disease Control and Prevention, 2020; Main et al., 2015, 2016). The SMM index includes 21 potentially fatal conditions and life-saving procedures related to pregnancy, labor, or delivery, identified using ICD diagnosis and procedure codes (Supplemental Table 1). Individuals who had at least one of these 21 indicators were classified as cases. SMM was determined from hospital discharge record, which included up to 25 ICD diagnosis codes and 25 procedure codes per admission.

Due to the lack of information on the volume of transfusion in administrative data and concerns about inconsistency in hospital-reported transfusion, including cases with blood transfusion as the sole indicator may include cases with only low-volume transfusion, resulting in the overestimation of SMM cases (Grobman et al., 2014; Leonard et al., 2019; Main et al., 2016). We undertook sensitivity analysis to assess non-transfusion SMM cases as the outcome.

3.3. Gentrification

We measured gentrification using three exposure assessment methods: Freeman method, Landis method, and Displacement and Gentrification Typology. Neighborhood was defined as census tract, a commonly used census-based boundary with approximately 4000 residents (United States Census Bureau, n.d., n. d.). We used metropolitan and micropolitan statistical areas as the urban regional boundaries in which neighborhoods are located, linked to census tracts via counties using the Federal Information Processing System code. Across all three exposure assessment methods, for census tracts within their respective metropolitan and micropolitan statistical areas, the neighborhood-level characteristic is compared with its corresponding regional characteristic. For example, one criterion of gentrification assessed whether neighborhood-level median household income increased more than regional level change in median household income during the specified period. Neighborhood and regional changes were measured across two ten-year periods and gentrification measures were linked to births based on birth year. The first period, spanning from 2000 to 2010, was characterized using the 2000 Decennial Census and the 2008–2012 American Community Survey (ACS) 5-Year Estimate. The second period, starting in 2007 and ending in 2017, used the 2005–2009 and 2015–2019 ACS 5-Year Estimate (Supplemental Table 2). The 2000 census data were normalized to 2010 boundary using the Longitudinal Tract Data Base (Logan et al., 2014, 2016). We implemented a five-year lag between the start of the gentrification period and the first year of the corresponding linked births to increase the likelihood that the neighborhood was experiencing the measured changes when the birth occurred (Supplemental Table 2).

3.4. Freeman method

Using Decennial Census and American Community Survey data, this exposure assessment method classified neighborhood gentrification status based on changes in socioeconomic characteristics. A census tract was classified as eligible to gentrify if, at the beginning of the period, 50% of the census blocks within the tract were urban, and the tract-level median household income as well as the percentage of housing built in the prior 20 years was lower than or equal to the regional value. Otherwise, the tract was classified as excluded

(not eligible for gentrification). Census tracts that were eligible for gentrification were then dichotomously classified into gentrifying and non-gentrifying tracts. A census tract eligible for gentrification was classified as gentrifying if it saw an increase in median home value and percentage of residents with a bachelor's degree that was larger than the regional (metropolitan/micropolitan statistical area) change in these two characteristics over a ten-year period. A tract that was eligible for gentrification but did not gentrify was classified as stable. Stable tracts were used as the referent group. The Freeman method classified census tracts as: eligible for gentrification and gentrifying, eligible for gentrification and stable, and excluded. This method and its variations are commonly used in epidemiologic and social sciences literature (Bhavsar et al., 2020; Ding et al., 2016; Gibbons and Barton, 2016; Hammel and Wyly, 1996).

3.5. Landis method

The Landis 3-D methodology measures neighborhood socioeconomic changes using an income variable (Landis, 2015). Within each region, census tracts were ranked into deciles based on their median household income. A census tract was classified as gentrifying if it was in the bottom four deciles at the beginning of the period and had moved up by two or more deciles by the end of the period. Comparatively, if a census tract was in the top four deciles at the beginning of the period and declined by two or more deciles by the end of the period, it was classified as declining. If a census tract did not fall into either the gentrifying or the declining category, it was classified as stable. Stable tracts were used as the referent group.

3.6. Displacement and Gentrification Typology

The Displacement and Gentrification Typology was originally developed by the Urban Displacement Project as a Neighborhood Early Warning System, a tool that tracks investment and sociodemographic changes at the neighborhood-level to enable identification of and intervention upon neighborhood changes before patterns become entrenched (Chapple and Zuk, 2016). In addition to using census data like the Freeman and Landis 3-D methods, this Typology also leveraged Zillow Home Value Index to classify neighborhoods into displacement, gentrification, or exclusive categories. This Typology identified low- and middle-income neighborhoods that were susceptible to or were experiencing displacement and gentrification, as well as high-income neighborhoods where the housing market was becoming exclusionary. Neighborhoods were classified into nine categories based on neighborhood household income and housing affordability. Details are described in Supplemental Table 3. For this analysis, we classified the nine categories into three broad stages of neighborhood change to enable comparison with the other two exposure assessment methods: Displacement (Low Income/Susceptible to displacement, Ongoing displacement of low-income households), Gentrification (At risk of gentrification, Early ongoing gentrification, Advanced Gentrification), and Exclusive (Stable moderate/Mixed income, At risk of becoming exclusive, Becoming exclusive, Stable/Advance exclusive). Tracts classified as "Exclusive" were used as the referent group. We made a small modification to the "Becoming Exclusive" category by excluding the criterion of in-migration rate due to data availability. Materials on this measure can be found at https://github.com/urban-displacement/displacement-typologies.

Comparing across the three exposure assessment methodologies, the Freeman method and its variations have been the most commonly used in epidemiologic studies (Bhavsar et al., 2020; Freeman, 2005; Schnake-Mahl et al., 2020). This method considers multiple dimensions of neighborhood changes such as education and income. The Landis method utilizes a single indicator of relative change in median household income which is straightforward to assess (Landis, 2015). By comparing the Landis method to the Freeman method, we examined whether a simplified measurement can as effectively measure gentrification (Supplemental Table 4). The Displacement and Gentrification Typology, on the other hand, has a stronger emphasis on housing affordability as a key component of neighborhood change and accounts for spatial proximity to tracts with increasing housing costs. This Typology's distinction between gentrification and displacement, which usually precedes but sometimes follows or overlaps with gentrification, also enables a more nuanced understanding of neighborhood changes compared to the other two methodologies (Chapple, 2017).

3.7. Covariates

Covariates included sociodemographic factors: birthing person age (years), education (less than high school, high school, some college, college or postgraduate degree), and principal source of payment at delivery (private insurance, Medicaid, uninsured or other), and pregnancy-related factors: parity (any or no prior live births), plurality of birth (singleton or multiple birth type), and having any co-morbidity. Using ICD Clinical Modification 9th and 10th Revision codes, birthing people were classified as having co-morbidities if they had any of the following conditions: gestational hypertension or diabetes, preeclampsia, pre-conceptional diabetes, chronic hypertension, or asthma (Hirshberg and Srinivas, 2017; Leonard et al., 2020).

We used self-reported information on birth certificates to determine the birthing person's race and ethnicity. The categories were non-Hispanic Black (Black/African American), non-Hispanic Asian/Pacific Islander (API: Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, Native Hawaiian, Guamanian or Chamorro, Samoan, other Asian, and Pacific Islander), American Indian/Alaska Native (AIAN), Hispanic (Hispanic/Latinx), and non-Hispanic White. We used race and ethnicity as a proxy to measure the past and present social marginalization that racialized people experience, which we hypothesized as particularly relevant to the racialized process of gentrification (Jones, 2001; Lett et al., 2022).

3.8. Statistical analysis

We examined the distribution of individuals' characteristics and their neighborhood gentrification status overall and by whether they experienced SMM. Further, we examined gentrification status, according to each of the 3 measures, by participant race and ethnicity.

To assess associations between gentrification and SMM, we used mixed-effects logistic regression models, with a random intercept to account for individuals clustering within neighborhoods (Raudenbush and Bryk, 2002). We sequentially adjusted for covariates. Model 1 adjusted for the birthing person's age, education, and insurance type to assess

the impact of gentrification on SMM independent of individual sociodemographic factors; We further adjusted for pregnancy and health-related factors including parity, plurality, and having any co-morbidity to investigate whether the associations between gentrification and SMM persist above and beyond clinical factors' contribution to SMM risk (Model 2). We selected Model 1 as the main model since pregnancy-related factors may also be mediating the associations. potentially resulting in overadjustment. To investigate whether gentrification influenced SMM risk differentially across racial and ethnic groups, we assessed effect measure modification by race and ethnicity using interaction terms between gentrification and race and ethnicity (e. g., neighborhood gentrification status x race and ethnicity) and used a critical value of $\alpha = 0.10$ to assess the significance of the interaction term (Selvin, 2004). If the interaction term is significant, we conducted race and ethnicity-stratified analysis, following the same sequential adjustment sets as the overall analysis.

We combined Asian and Pacific Islander individuals in our main analysis due to the small sample size of Pacific Islander individuals and similar findings for both groups (N = 27,112). However, recognizing that there may be within-group differences between Asian and Pacific Islander individuals in the broader API group, disaggregated results are presented in Supplemental Table 5 (Srinivasan and Guillermo, 2000).

4. Results

Of the 5,256,905 births in the final analytic sample, 1.4% or 72,718 births were classified as SMM cases. The mean age was 28.7 years (SD = 6.21), and the sample was 27.5% White, 5.8% Black, 14.5% API, 51.7% Hispanic, and 0.4% AIAN. Table 1 displays the distribution of participant characteristics by SMM status. Overall, people who experienced SMM were more likely to be more than 35 years old, had lower educational attainment, and had public insurance. The proportion of birthing people with SMM was 1.1% among White individuals, 2.2% among Black individuals, 1.4% among API and Hispanic individuals, and 1.8% among AIAN individuals. In terms of pregnancy-related factors, those with SMM were more likely to have been primiparous, have multi-fetal gestation, and have co-morbidities.

The proportion of birthing people living in a gentrifying neighborhood varied across exposure assessment methods: 6.4% using Freeman, 11.7% using Landis 3-D, and 5.7% using Displacement and Gentrification Typology (Table 1). Additionally, this Typology classified 31.2% of birthing people as living in a tract undergoing displacement (a stage of neighborhood change involving the loss of marginalized and/or low-income households that may precede, accompany, or follow gentrification) (Zuk et al., 2018). Compared to the overall study population, birthing people living in gentrifying tracts were more likely to be Black, across all three exposure measures. The racial and ethnic groups that were less likely to live in gentrifying tracts varied across the exposure methods: API birthing people using the Freeman method, Hispanic birthing people using the Landis group, and White birthing people using the Displacement and Gentrification Typology (Table 2). Across the 7, 575 census tracts in the study, there was little consistency in whether a tract was classified as gentrifying across the three methods, with the overlap ranging from 2% between the Landis method and the Displacement and Gentrification Typology to 19.3% between the Freeman method and Landis method. (Supplemental Table 6).

As shown in Table 3, results from mixed-effects models examining gentrification, as measured by the Freeman method, showed that independent of individual-level SES, living in a gentrifying tract was associated with lower risk of SMM overall (OR = 0.89, 95% CI: 0.86–0.93). Results remained similar after adjusting for pregnancy-related factors. Statistical tests indicated that race and ethnicity significantly modified the association between Freeman-measured gentrification and SMM when adjusting for sociodemographic factors (interaction term p-value = 0.067). Race and ethnicity-stratified models showed similar results among White (OR = 0.89, 95% CI: 0.83–0.96), Black (OR = 0.89, 95% CI: 0.80–0.98), and Hispanic individuals (OR = 0.91, 95% CI: 0.87–0.96). The direction of the association was the same among API and AIAN individuals, but the confidence intervals included the null. There were no statistically significant associations between gentrification measured using the Landis method and SMM risk in the overall sample or effect measure modification by race and ethnicity.

In comparison, gentrification, as measured by the Displacement and Gentrification Typology, was associated with higher SMM risk (OR = 1.18, 95% CI = 1.14–1.23), adjusting for sociodemographic factors. Adjusting for pregnancy-related factors did not change this association. The birthing person's race and ethnicity modified this association (interaction term p-value = 0.0012). The harmful impact of gentrification on SMM was consistently observed among White (OR = 1.27, 95% CI: 1.16–1.39), Black (OR = 1.21, 95% CI: 1.09–1.33), and Hispanic (OR = 1.11, 95% CI: 1.06–1.16) birthing people. Although results for API and AIAN birthing people contained the null, the direction of the association between gentrification and SMM risk was similar, and the magnitude was larger compared to other racial and ethnic groups. Living in a neighborhood experiencing displacement was also associated with higher SMM risk (OR = 1.09, 95% CI = 1.07–1.12) overall and within Black, Hispanic, API, and White groups, though the magnitude of association was slightly smaller among Hispanic birthing individuals (Table 3).

Sensitivity analysis assessing associations between gentrification and SMM after excluding transfusion-only SMM showed similar results (Table 4). Overall, associations between Freeman- and Typology-measured gentrification and SMM were slightly larger in magnitude, but precision decreased such that some confidence intervals contained the null after excluding transfusion-only cases.

5. Discussion

Leveraging data from a population-based cohort in California, this study assessed associations between neighborhood-level gentrification and SMM risk, using three exposure assessment methods. The Freeman measure and its variations, leveraging census information to characterize gentrification as neighborhood-level changes in sociodemographic variables, are the standard methodology used to assess gentrification in the social sciences and epidemiologic literature. Using this method, findings showed that gentrification was associated with a lower risk of SMM. We also assessed gentrification using the Landis method to explore whether a simplified measure would be comparable to the more multi-dimensional and commonly-used Freeman measure. We found that Landis-measured neighborhood gentrification or decline was not associated with SMM, suggesting that

using a gentrification measure focused solely on neighborhood income changes may not effectively capture the impact of gentrification on SMM. Lastly, we found that gentrification was positively associated with SMM risk using the Displacement and Gentrification Typology, which incorporates data on housing affordability and identifies multiple stages of gentrification. This measure, as an example of Neighborhood Early Warning Systems commonly used by local governments and planning organizations, may be valuable in future investigations of pregnancy-related complications. Lastly, we found that within race and ethnicity-stratified groups, the directions of the association were fairly consistent with results in the overall study sample, though the magnitude of the associations varied somewhat across racial and ethnic groups. These findings inform a more robust understanding of how gentrification impacts SMM risk for groups that have experienced differential exposure to social marginalization.

Findings from this study provide preliminary evidence that gentrification may be an important place-based factor shaping SMM risk. Existing literature has investigated gentrification's influence on preterm birth (Huynh and Maroko, 2014). Other studies exploring gentrification or neighborhood socioeconomic changes, which may share some features of gentrification such as an increase in group-level SES, have also documented associations with infant outcomes, as well as with risk factors for SMM, including chronic diseases such as hypertension, asthma, and stress (English et al., 2003; Iyanda and Lu, 2021; Margerison-Zilko et al., 2015; Morenoff et al., 2007; Tran et al., 2020). Additionally, the finding that Typology-measured displacement was associated with greater SMM risk is consistent with existing evidence on how housing instability or eviction, a potential cause of displacement, can have negative consequences for birthing people (Carrion et al., 2015; Desmond and Kimbro, 2015; Himmelstein and Desmond, 2021; Khadka et al., 2020). Findings from this study highlight the importance of investigating the role gentrification plays in influencing birthing people's pregnancy outcomes.

Equally notable was that the direction of the associations between gentrification and SMM depended on the method used to measure gentrification. There is little consensus on how gentrification is conceptualized and measured in the existing literature, and the variability in the exposure assessment methodologies may explain the heterogeneity in findings across studies. The Freeman method included a broad range of indicators on a neighborhood's education and income composition. In comparison, the Displacement and Gentrification Typology, in addition to considering neighborhood socioeconomic status, leveraged more detailed information on housing affordability to low-, medium-, and high-income households as well as spatial proximity to neighborhoods experiencing increasing housing cost. Our findings suggest that the limited availability and affordability of housing may be a harmful feature that is particularly salient for SMM outcomes. In contrast, when gentrification is operationalized as upward trajectory in neighborhood socioeconomic changes, using the Freeman measure, the captured influence may be protective against SMM risk. Landis 3-D gentrification measure was not associated with SMM, suggesting that changes in median household income alone may not capture critical elements of gentrification that matter for pregnancy-related outcomes. Further, the Typology measured displacement, while the Landis 3-D methodology measured decline in neighborhood income, which was conceptualized as mutually exclusive from gentrification.

The finding that Typology-measured displacement was associated with SMM demonstrates the importance of more nuanced investigations into the various stages and forms of dispossession and upheaval that occur during gentrification. Future studies with broader geographic coverage or larger sample size should examine the nine categories of the Displacement and Gentrification Typology, expanding beyond the three-level classification we chose to use in this study. Lastly, whether a neighborhood was classified as gentrifying varied considerably depending on the methodology used, which is consistent with a previous study in the San Francisco Bay Areas (Mujahid et al., 2019). Overall, these findings highlight that the conceptualization and measurement of gentrification matter when examining effects on pregnancy-related outcomes. Future studies on gentrification should explicate a robust conceptualization of how the various aspects of gentrification may affect pregnancy outcomes, and select a measure that most closely operationalizes this conceptualization, especially given our finding that gentrification classification had little overlap across three methodologies. Additionally, understanding the full impact of gentrification on pregnancy-related outcomes will require the development of new measures that capture gentrification elements beyond the neighborhood socioeconomic changes, empathized by the Freeman and Landis methods, including housing inequality, rent burden, and community disintegration. The measures should also address the extent to which gentrification is driven by state-level factors, such as zoning policies, tax incentives, policing, public infrastructure projects, and private sector practices, including real estate development, neighborhood marketing, and investment in businesses.

Our study assessed whether gentrification's influence on SMM risk varied across racial and ethnic groups. Although gentrification has been largely theorized as a market-driven economic process, neighborhood social and material conditions have been and are continuously shaped through policies and programs such as urban renewal, deindustrialization, and White flight, which disproportionately harmed Black communities and other racially marginalized people (Fallon, 2021; Fullilove, 2001; Rucks-Ahidiana, 2021b). A study conducted in New York City, using multiple census-based socioeconomic indicators to measure gentrification, found that very high gentrification was associated with increased odds of preterm birth among non-Hispanic Black birthing people but was protective against preterm birth among non-Hispanic White birthing people (Huynh and Maroko, 2014). Using the Freeman measure, our finding that gentrification was protective against SMM among White birthing people is consistent with this study; however, this direction of association was also observed overall and among Black, Hispanic, and API birthing people. In contrast, the findings that displacement and gentrification, measured using the Typology, are associated with increased risk of SMM among Black birthing people are consistent with quantitative and qualitative evidence (Chambers et al., 2021; Gibbons and Barton, 2016; Huynh and Maroko, 2014; Izenberg et al., 2018). For example, a study conducted in Northern California interviewed Black birthing people in various reproductive stages, and reported that lack of housing due to gentrification, as well as the inability to access neighborhood resources, are key features of structural racism that matter for reproductive health (Chambers et al., 2021).

Findings from this study also contribute evidence about the impact of gentrification on Hispanic and API birthing people's pregnancy outcomes, and provide direction for future

examination of the differential effects of gentrification. Latinx and Asian neighborhoods in California are navigating and contesting neighborhood commercial, housing, and transit development, and how these processes impact the wellbeing of birthing people in these communities (Romero et al., 2022). Due to the small sample size of AIAN birthing people, statistical analysis lacked the power to detect significant associations. However, SMM rates are the among the highest in Indigenous populations, who have been seriously impacted by the housing crisis and gentrification (NoiseCat, 2021). Future studies should employ study designs that can differentiate between individuals who are long-term residents and who are in-movers relocating into a gentrifying neighborhood to assess whether the associations observed in this study are uniform, given that racialized people have historically been more vulnerable to dispossession and displacement. Furthermore, this distinction may also provide insight about the influence of gentrification observed among White individuals; for example, whether White long-term residents or newcomers moving into a gentrifying neighborhood are experiencing the harmful impact of Typology-measured gentrification. Lastly, investigations are needed to understand whether gentrification affects birthing people's well-being differentially across neighborhoods with different racial composition or residential segregation status. For example, residents in predominantly White neighborhoods and predominantly Black neighborhoods may experience gentrification differently (Hwang, 2020; Hwang and Sampson, 2014; Rucks-Ahidiana, 2021a).

This study has several strengths, including the comparison of three gentrification assessment methodologies, usage of a large population-representative state-wide sample, validated measurement of SMM, and adjustment for sociodemographic confounders and pregnancy-related factors. Limitations include potential misclassification of SMM outcomes due to the use of administrative hospital discharge data or the inclusion of people who received a blood transfusion for non-severe complications (Lydon-Rochelle et al., 2005; Main et al., 2016). However, sensitivity analyses excluding blood transfusion-only cases showed comparable results. Second, although we were able to create a lag between the beginning of the neighborhood change period and birth years, a longitudinal study design can ensure better temporality and reduce the likelihood of exposure misclassification. Another challenge related to study design was that we did not have information on the individuals' length of residency or their residential mobility, which may have resulted in uncontrolled confounding. Longitudinal datasets may also enable the assessment of health impact for those who were displaced from gentrifying neighborhoods (Pearl et al., 2018). Further, we examined changes over the course of ten years, but the pace of gentrification may be quicker or slower at specific time points, and the pace may also vary across regions and cities in California. Future studies can explore other length of neighborhood change periods and utilize local context and knowledge if focusing on specific cities or regions. While we assessed multiple measures of gentrification, the referent group differed between the three methodologies, with "Stable" being the referent for the Freeman and Landis methods, and "Exclusive" being the referent for the Displacement and Gentrification Typology, which are neighborhoods that are becoming or have become inaccessible to low-income households, and the study sample in this category had better SES characteristics, compared to the other two measures' referent group. Lastly, exclusion of individuals from the analytic sample due to missing covariate information may have contributed to bias.

In conclusion, findings from this study contribute to the accumulating body of evidence that gentrification plays a role in shaping pregnancy-related outcomes among birthing people. Furthermore, how gentrification is conceptualized and measured may explain the heterogeneity in the direction of association with SMM risk that we observed. Future studies should examine how the ongoing process of gentrification, as situated within a long history of neighborhood changes and upheaval shaped by structural forces, contributes to racial and ethnic inequities in adverse pregnancy-related mortality and morbidity outcomes. Evidence on the health impact of gentrification can inform policies and programs that support equitable neighborhood development and prevent adverse pregnancy-related outcomes resulting from gentrification and displacement among marginalized populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Sources of financial support

This research was supported by the National Institute of Nursing Research (5R01NR017020-04; 1R01NR020335-01) and the Eunice Kennedy Shriver National Institute of Child Health and Human Development (5F31HD106772-02).

Data availability

The authors do not have permission to share data.

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Table 1

Participant characteristics by SMM status, California, 2006–2017 (N = 5,256,905).

	Overall	No SMM	SMM
n	5,256,905	98.6	1.4
Freeman			
Stable	1,333,646 (25.4)	25.3	28.3
Excluded	3,585,831 (68.2)	68.3	65.3
Gentrifying	337,428 (6.4)	6.4	6.5
Landis			
Stable	4,192,622 (79.8)	79.7	80.4
Declining	450,994 (8.6)	8.6	8.3
Gentrifying	613,289 (11.7)	11.7	11.7
Displacement and Gentrification Typology			
Exclusive	3,315,328 (63.1)	63.1	59.6
Displacement	1,642,464 (31.2)	31.2	33.8
Gentrifying	299,113 (5.7)	5.7	6.6
Age			
<20	390,674 (7.4)	7.4	8.6
20–34	3867,434 (73.6)	73.7	67.4
≥35	998,797 (19.0)	18.9	24.1
Race/Ethnicity			
White	1,445,935 (27.5)	27.6	22.7
Black	305,972 (5.8)	5.8	9.1
Asian or Pacific Islander	765,222 (14.6)	14.6	14.9
Hispanic	2,718,935 (51.7)	51.7	52.8
American Indian/Alaskan Native	20,841 (0.4)	0.4	0.5
Education			
Less than High school	1,197,131 (22.8)	22.7	25.0
High School	1,331,471 (25.3)	25.3	26.2
Some College	1,303,405 (24.8)	24.8	24.1
College/Graduate School	1,424,898 (27.1)	27.1	24.6
Payment Type at Delivery			
Private	2,510,134 (47.7)	47.8	44.2
Medi-Cal	2,554,635 (48.6)	48.5	52.4
Uninsured or Other	192,136 (3.7)	3.7	3.4
Multiple Birth	81,842 (1.6)	1.5	6.3
Primiparous	2,033,527 (38.7)	38.6	43.4
Any comorbidity	1,017,245 (19.4)	19.1	37.1

Overall distribution is displayed by count and percentage in parenthesis; distribution by SMM status is displayed by column percentage.

Table 2

Gentrification Status by race and ethnicity Status, California, 2006–2017 (n = 5,259,206).

	Overall (n = 5,256,905)	White (n = 1,445,935)	Black (n = 305,972)	Asian & Pacific Islander (n = 765,222)	Hispanic (n = 2,718,935)	American Indian & Alaskan Native (n = 20,841)
Freeman						
Stable	1,333,646 (25.4)	14.5	33.8	17.0	32.6	22.8
Excluded	3,585,831 (68.2)	79.0	57.4	78.0	61.0	69.1
Gentrifying	337,428 (6.4)	6.5	8.9	5.0	6.5	8.0
Landis						
Stable	4,192,622 (79.8)	77.6	80.1	78.0	81.3	81.6
Declining	450,994 (8.6)	9.3	7.5	10.4	7.8	7.2
Gentrifying	613,289 (11.7)	13.1	12.3	11.6	10.9	11.1
Displacement and Gentrification Typology						
Exclusive	3,315,328 (63.1)	81.0	45.6	77.1	51.5	64.3
Displacement	1,642,464 (31.2)	16.5	46.9	18.0	41.1	30.6
Gentrifying	299,113 (5.7)	2.5	7.5	4.9	7.4	5.1

Overall distribution is displayed by count and percentage in parentheses; distribution by race/ethnicity is displayed by column percentage.

Table 3

Adjusted odds ratios of SMM by gentrification and maternal race and ethnicity; California, 2006–2017 (n = 5,256,905).

	Overall		White		Black		Hispanic		API		AIAN	
	Model 1 OR (95% CI)	**Model 2 OR (95% CI)**	**Model 1 OR (95% CI)**	**Model 2 OR (95% CI)**	**Model 1 OR (95% CI)**	**Model 2 OR (95% CI)**	**Model 1 OR (95% CI)**	**Model 2 OR (95% CI)**	**Model 1 OR (95% CI)**	**Model 2 OR (95% CI)**	**Model 1 OR (95% CI)**	**Model 2 OR (95% CI)**
Freeman												
Stable	–	–	–	–	–	–	–	–	–	–	–	–
Exduded	0.88 (0.87–0.90)	0.89 (0.88–0.91)	0.84 (0.80–0.88)	0.86 (0.83–0.90)	0.98 (0.92–1.03)	0.99 (0.94–1.05)	0.91 (0.89–0.94)	0.92 (0.90–0.95)	0.88 (0.83–0.93)	0.89 (0.84–0.94)	0.81 (0.64–1.03)	0.82 (0.65–1.05)
Gentrifying	0.89 (0.86–0.93)	0.90 (0.87–0.94)	0.89 (0.83–0.96)	0.90 (0.83–0.96)	0.89 (0.80–0.98)	0.90 (0.82–1.00)	0.91 (0.87–0.96)	0.92 (0.88–0.97)	0.92 (0.83–1.01)	0.92 (0.84–1.02)	0.65 (0.41–1.03)	0.65 (0.41–1.04)
Landis												
Stable	–	–	–	–	–	–	–	–	–	–	–	–
Declining	0.98 (0.95–1.01)	0.97 (0.94–1.00)	1.00 (0.95–1.06)	0.99 (0.93–1.05)	0.97 (0.88–1.07)	0.95 (0.86–1.05)	0.97 (0.93–1.01)	0.96 (0.92–1.01)	1.01 (0.95–1.08)	1.01 (0.94–1.08)	0.82 (0.53–1.26)	0.81 (0.52–1.26)
Gentrifying	0.98 (0.95–1.01)	0.98 (0.95–1.01)	0.99 (0.94–1.04)	0.99 (0.94–1.04)	0.95 (0.87–1.03)	0.95 (0.88–1.03)	0.97 (0.94–1.01)	0.98 (0.94–1.02)	1.01 (0.95–1.08)	1.00 (0.94–1.07)	0.74 (0.51–1.08)	0.73 (0.50–1.07)
Displacement and Gentrification Typology												
Exdusive	–	–	–	–	–	–	–	–	–	–	–	–
Displacement	1.09 (1.07–1.12)	1.09 (1.07–1.11)	1.10 (1.06–1.15)	1.08 (1.03–1.13)	1.10 (1.04–1.16)	1.08 (1.02–1.14)	1.04 (1.02–1.07)	1.04 (1.02–1.07)	1.08 (1.02–1.13)	1.07 (1.01–1.12)	1.06 (0.84–1.33)	1.06 (0.84–1.34)
Gentrifying	1.18 (1.14–1.23)	1.18 (1.13–1.22)	1.27 (1.16–1.39)	1.23 (1.12–1.35)	1.21 (1.09–1.33)	1.18 (1.07–1.30)	1.11 (1.06–1.16)	1.11 (1.06–1.16)	1.10 (1.00–1.20)	1.09 (1.00–1.20)	1.48 (0.98–2.24)	1.47 (0.97–2.23)

OR: Odds Ratio.

Model 1 adjusted for age, education, and insurance type.

Model 2 adjusted for covariates in Model 1 and parity, plurality, and having any comorbidity.

Intraclass Correlation Coefficient for overall sample: Freeman Models = 0.02; Landis Models = 0.02; Typology Models = 0.02.

Table 4

Adjusted odds ratios of non-transfusion SMM by gentrification and maternal race and ethnicity; California, 2006–2017(n = 5,214,369).

	Overall		White		Black		Hispanic		API		AIAN	
	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Freeman												
Stable	–	–	–	–	–	–	–	–	–	–	–	–
Exduded	0.85 (0.83–0.88)	0.87 (0.85–0.90)	0.82 (0.77–0.88)	0.85 (0.80–0.91)	0.91 (0.84–0.99)	0.93 (0.85–1.00)	0.89 (0.86–0.93)	0.91 (0.87–0.94)	0.84 (0.78–0.91)	0.85 (0.79–0.92)	0.76 (0.51–1.14)	0.87 (0.52–1.16)
Gentrifying	0.87 (0.82–0.91)	0.87 (0.83–0.92)	0.89 (0.80–0.99)	0.90 (0.81–1.00)	0.88 (0.76–1.02)	0.89 (0.78–1.03)	0.87 (0.81–0.93)	0.88 (0.82–0.95)	0.79 (0.68–0.92)	0.80 (0.69–0.93)	0.69 (0.33–1.44)	0.70 (0.33–1.47)
Landis												
Stable	–	–	–	–	–	–	–	–	–	–	–	–
Dedining	0.98 (0.94–1.01)	0.97 (0.93–1.02)	0.98 (0.90–1.07)	0.97 (0.89–1.05)	0.98 (0.85–1.13)	0.96 (0.83–1.10)	0.99 (0.90–1.01)	0.99 (0.93–1.05)	0.99 (0.90–1.09)	0.99 (0.91–1.09)	0.89 (0.51–1.57)	0.58 (0.25–1.34)
Gentrifying	0.97 (0.94–1.01)	0.98 (0.94–1.01)	1.03 (0.95–1.10)	1.03 (0.95–1.10)	0.90 (0.80–1.01)	0.90 (0.80–1.02)	0.95 (0.90–1.01)	0.96 (0.91–1.02)	1.00 (0.92–1.10)	0.99 (0.91–1.09)	0.89 (0.26–1.35)	0.88 (0.50–1.56)
Displacement and Gentrification Typology												
Exdusive	–	–	–	–	–	–	–	–	–	–	–	–
Displacement	1.13 (1.09–1.16)	1.11 (1.08–1.14)	1.14 (1.07–1.21)	1.10 (1.03–1.17)	1.20 (1.10–1.30)	1.18 (1.09–1.28)	1.06 (1.02–1.10)	1.05 (1.01–1.09)	1.06 (0.98–1.15)	1.04 (0.96–1.13)	0.96 (0.65–1.42)	0.96 (0.65–1.43)
Gentrifying	1.22 (1.16–1.29)	1.21 (1.15–1.27)	1.36 (1.19–1.55)	1.30 (1.14–1.49)	1.23 (1.06–1.42)	1.20 (1.04–1.38)	1.17 (1.10–1.25)	1.17 (1.09–1.24)	1.03 (0.90–1.18)	1.03 (0.90–1.18)	0.88 (0.38–2.07)	0.88 (0.37–2.07)

Model 1: adjusted for age, education, and insurance type.

Model 2: adjusted for covariates in Model 1 and parity, plurality, and having any comorbidity.