

Association of Neighborhood-Level Social Vulnerability with Preterm Birth in King County,
Washington, 2018-2022

Neil Panlasigui

A thesis

Submitted in partial fulfillment of the
Requirements for the degree of

Master of Public Health (Epidemiology- Maternal and Child Health track)

University of Washington

2024

Thesis Committee:

Daniel A. Enquobahrie

Precious Esie

Program Authorized to Offer Degree:

Epidemiology

© Copyright 2024

Neil Anthony Panlasigui

University of Washington

Abstract

Association of Neighborhood-Level Social Vulnerability with Preterm Birth in King County,
Washington, 2018-2022

Neil Panlasigui

Chair of the Thesis Committee:

Daniel A. Enquobahrie

Department of Epidemiology

Background: Preterm birth (PTB) affects one in ten US infants and remains to be a leading cause of infant morbidity, mortality, and life course adverse health outcomes. In King County, WA, the rate of PTB is higher among Black (12.1%) and American Indian/Alaska Native (15.6%) birthing people, as well as those without a college degree (12.0%), when compared to King County's average (9.3%). Recent studies suggest that social determinants of health play a significant role in PTB risk. However, no prior study examined associations between social disadvantage and PTB risk in King County, as well as potential roles of race in this relationship. This study examined the association between social vulnerability index (SVI), a tool developed by CDC to characterize social vulnerability, and PTB in King County, WA. It also examined the role of race as a potential effect modifier of the association.

Methods: This cross-sectional study used singleton birth data in King County, WA, from 2018 to 2022. Exposure was social vulnerability, defined using SVI quartiles (Q1, Q2, Q3, and Q4), while outcome was PTB, defined as birth before 37 weeks of gestation. Participants were excluded if they had missing exposure, outcome, or census tract information. The study analyzed data from 89,320 live singleton births in King County, WA. Three logistic regression models were fit to estimate odds ratios (ORs) and corresponding 95% confidence intervals (CIs). Model 1 (minimally adjusted) included exposure and outcome variables, along with birthing person's race/ethnicity and King County region. Model 2 (partially adjusted) included Model 1 variables and variables for infant sex, birthing person's age, educational attainment, marital status, and Women, Infant and Children (WIC) program status. Model 3 (fully adjusted) included Model 2 variables and variables for Kotelchuck index, parity, diabetes status, hypertension status, PTB history, and smoking status. Additionally, we fit logistic regression models stratified by race/ethnicity (Asian, Black, Hispanic, Multiple, Other/Unknown, and White) to compare associations across racial/ethnic groups. A likelihood ratio test was used to determine the statistical significance of differences in associations across race/ethnic groups.

Results: The majority (59%) of study participants were in the 25-34 years age group, non-White (54%) and South King County residents (43%). Over half (58%) held Bachelor's degree or higher, and the majority (78%) were married. About 54% were parous with no history of preterm birth (97%). Participants in the highest SVI quartile were younger (18% aged 18-24 years), unmarried (36%), enrolled in WIC (34%), racial minorities (69%), and South King County residents (75%), compared with participants in the lowest three SVI quartiles. PTB prevalence increased across increasing SVI quartiles: 6.2%, 6.8%, 7.5%, and 9.2% in the first, second, third, and fourth quartiles, respectively. In general, PTB prevalence was highest in Q4, and lowest in Q1, for all racial/ethnic groups except Black birthing people. In Model 1, the odds ratios of PTB risk for the upper three SVI quartiles, compared with Q1, were as follows: Q2

(OR:1.04, 95% CI: 0.96-1.13), Q3 (OR:1.08, 95% CI:1.00-1.17) and Q4 (OR:1.17, 95% CI:1.08-1.27) (trend p-value <0.001). In Model 2, the OR estimates for Q2 (OR:1.02, 95% CI: 0.94-1.11), Q3 (OR:1.04, 95% CI:0.96-1.13) and Q4 (OR:1.07, 95% CI:0.99-1.17) were closer to the null and became statistically insignificant (trend p-value=0.093). Findings from Model 3 were largely similar to findings from Model 2 (trend p-value=0.107). In stratified analysis using Model 2, the ORs across SVI quartiles suggested a positive SVI-PTB risk relationship among Asian residents (Q2 OR: 1.05, 95% CI: 0.90-1.23; Q3 OR: 1.09, 95% CI: 0.93-1.28; Q4 OR: 1.15, 95% CI: 0.96-1.37) (trend p-value=0.112), whereas among Black residents it suggested an inverse relationship (Q2 OR: 0.84, 95% CI: 0.56-1.27; Q3 OR: 0.79, 95% CI: 0.54-1.16; Q4 OR: 0.74, 95% CI: 0.51-1.07) (trend p-value=0.094). Model 3 findings of the stratified analyses were in general similar to Model 2 findings of the stratified analyses. The p-values for the likelihood ratio tests assessing the interaction between SVI quartiles and race/ethnicity on PTB risk were 0.011 for Model 1, 0.072 for Model 2, and 0.108 for Model 3.

Discussion: We found potential positive associations between SVI and PTB risk that varied across racial/ethnic groups (suggestive positive associations among Asians and suggestive inverse associations among Blacks). The estimates relating SVI and PTB were not statistically significant after adjusting for other variables in our models. This study suggests a potential relationship between SVI and PTB with significant public health implications. Future studies in this area are warranted to inform targeted program or policy interventions that address maternal and child health equity in the population.

BACKGROUND

The U.S. bears a substantial maternal and child health burden compared to other developed nations, exacerbated by widening health disparities among socially disadvantaged groups (1). In King County, WA, infant mortality rates among Black and American Indian and Alaska Native (AIAN) birthing people are 2.5 and 4 times higher, respectively, than those among White birthing people, echoing national trends (2). Additionally, elevated rates of preterm birth (PTB, birth before 37 completed weeks of gestation), a risk factor for infant mortality, have persisted among racial minorities and individuals with less than a college degree (2,3). In King County, WA, the rate of PTB is higher among Black (12.1%) and American Indian/Alaska Native (15.6%) birthing people, as well as those without a college degree (12.0%), when compared to King County's average (9.3%) (2). Recent frameworks linking PTB to social determinants of health emphasize the role of neighborhood socio-structural factors (such as education gaps, neighborhood deprivation, and residential segregation) as risk factors (4–6). However, roles of community-level factors reflecting social vulnerability in PTB risk have not been fully examined in King County, WA.

One tool designed to characterize social disadvantage is the Centers for Disease Control and Prevention's (CDC) social vulnerability index (SVI). SVI encompasses 16 community-level indicators grouped into four themes: socioeconomic status, household characteristics, racial and minority status, and housing type and transportation (7). Originally developed to assess community resources and preparedness, SVI has been used as a composite measure to characterize health disparities across a wide range of topics, including COVID-19 vaccine coverage, surgical outcomes and neighborhood violence (8–10). A recent study that was based on data from the National Center for Health Statistics, encompassing data on live births in the U.S. between 2007 and 2019, found positive associations between SVI and PTB (11). Another showed the association between SVI scores and PTB were stronger for Black birthing people than other racial/ethnic groups (12). In King County, WA, racism has been

declared a public health crisis, highlighting the urgency to understand factors driving racial disparities in adverse birth outcomes (13). Currently, there are no studies examining the link between SVI and PTB or the role of race/ethnicity in SVI-PTB associations among birthing people residing in King County, WA.

The primary aim of the study was to examine the association between SVI and PTB in King County. The secondary aim was to explore whether this association was modified by race/ethnicity. By analyzing the relationship between SVI at the census-tract level and PTB, the study sought to uncover neighborhood-level social vulnerability contributing to PTB risk, with the SVI serving as a composite measure of the relative vulnerability in an area. Given that race is a social construct, we conducted stratified analysis with race/ethnicity conceptualized as an effect modifier. Exploring how the relationship might vary by race/ethnicity could inform identification of susceptible populations and the development of culturally sensitive and effective public health strategies to address PTB burden. This approach aligns with the broader goal of reducing health inequities and improving maternal and infant health outcomes across diverse communities in King County, WA.

METHODS

Study Design and Study Setting

This multi-level, cross-sectional study used data from singleton births in King County, WA, from 2018 to 2022. The study was characterized as multilevel because data on SVI exposure, measured at the neighborhood level (census tracts), was examined in relation to outcome data (PTB risk) collected at the individual level. The study was conducted in collaboration with King County's Assessment, Policy, and Development (APDE) Unit.

Study Participants

The study examined data from 118,468 births occurring between 2018 and 2022 in King County, WA. Participants with multiple births (n=3,617) or had birth under 18 years of age (n=450), as well as participants with missing outcome (PTB) (n=238), census tract information (n=652) or missing covariates data (see *Statistical Analysis* below) (n=24,191) were excluded. The final analysis included 89,320 live singleton births from residents of one of 494 census tracts in King County. The University of Washington's Human Subjects Division reviewed the protocol on January 23, 2024 and determined that the project did not involve human subjects as defined by federal regulations. Therefore, the project did not require exempt status or IRB review.

Data Collection

Data regarding PTB, birthing person's age, race/ethnicity, educational attainment, infant sex, marital status, and King County region were extracted from Washington State Birth Filing Forms that are collected and maintained by the Washington State Department of Health Center for Health Statistics. The county of residence for each case was assigned based on the birthing person's address at the time of birth, as listed on the birth certificate. The dataset only included King County residents. Additional information on diabetes status, hypertension status,

Kotelchuck index, parity, preterm birth history, smoking status, and Women, Infants, and Children (WIC) program status, was extracted from the WA State Birth Filing Form, specifically from the section labeled "For Hospital Use Only," and obtained through King County's APDE births dataset (14).

Exposure, Outcome, and Covariates

In this study, exposure was quantified using CDC's 2020 SVI instrument, applied at the level of census tracts as provided by King County's APDE Unit (15). The overall SVI score (0-1) used for this study reflected percentile ranks of the census tracts based on the total scores for all the themes. The score of 0 represented the lowest level of social vulnerability and a score of 1 indicated the highest level of social vulnerability. For analytical purposes, these SVI scores were divided into quartiles (Q1-Q4). Of note, these groups are based on the quartile cutoffs for SVI scores (corresponding to census tracts), thus the proportion of participants included in each quartile varied significantly from 25%.

PTB in this study was defined as a binary outcome (0 or 1), with births occurring before 37 completed weeks of gestation coded as 1. Additional covariates were categorized as follows: infant sex (Female/Male), birthing person's age in years (18-24, 25-34, 35-39, and 40+), birthing person's race/ethnicity (Asian, Black, Hispanic, Multiple, Other/Unknown, White), educational attainment (Less than high school, up to 8th grade/Some high school, High school graduate/GED, Some college or associate's degree, Bachelor's degree, and Graduate or professional degree), marital status (Married/Not married), King County Region (East, North, Seattle, South), WIC program status (WIC participant/Non-participant), Kotelchuck Index ($\geq 80\%$, $< 80\%$), parity (Nulliparous or Parous), diabetes status (Pre-pregnancy diabetes/No diabetes), hypertension status (Pre-pregnancy hypertension/No hypertension), preterm birth history (History of PTB/No PTB history), and smoking status (Non-smoker, Former Smoker, Smoked during pregnancy). Given their lower representation in our dataset, individuals identified as

Native American Alaska Native (AIAN) and Native Hawaiian or Pacific Islander (NHPI) were grouped into the 'Other/Unknown' race/ethnicity category to maintain statistical robustness and confidentiality.

Statistical Analysis

Descriptive statistics (number and %) were used to characterize the study population overall and across SVI quartiles. We examined the prevalence of PTB overall and by SVI quartiles and race/ethnicity groups. To address the first aim, examining the relationship between SVI and PTB in King County, we fitted three logistic regression models. To address potential clustering of outcomes based on geographical location, all models were adjusted for King County Region (East, North, South, and Seattle). Consequently, all models were treated as fixed-effect models. Model 1 (minimally adjusted model) included the exposure (SVI), the outcome (PTB), birthing person's race/ethnicity, and a variable for King County Region. Model 2 (partially adjusted model) included Model 1 variables as well as variables for infant sex, birthing person's age, educational attainment, marital status, and WIC program status. Model 3 (fully adjusted model) included variables for Kotelchuck Index, parity, diabetes status, hypertension status, preterm birth history, and smoking status, in addition to variables included in Model 2. Odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were used to estimate associations of SVI quartiles with PTB, using the first quartile (Q1) of SVI as a reference. Additionally, SVI quartiles were reparametrized as a continuous variable (ranging from 1-4, corresponding to quartiles 1, 2, 3, and 4) and fitted into the models to assess linear trends of the SVI and PTB relationship.

To address the second aim, exploring effect modification by race/ethnicity groups, logistic regression Models 1, 2 and 3 (described above) were fit, stratified by birthing person's race/ethnicity. To assess the statistical significance of interactions between SVI quartiles and race/ethnicity, we conducted likelihood ratio tests (LRTs), comparing adjusted models with

versus without the interaction term (SVI-race/ethnicity interaction). Statistical significance was determined using an alpha level of 0.05, and effect size was estimated using ORs and corresponding 95% CIs. All analyses were conducted using R (RStudio 2023.12.0+369 "Ocean Storm").

RESULTS

Most participants resided in census tracts within the South King County Region (42.9%), followed by the Seattle Region (29.1%), East Region (23%), and North Region (5%) (**Table 1**). The largest racial group consisted of White birthing people (46.3%), and the remaining participants were racial minorities—Asian (23.2%), Hispanic (14%), Black (8.8%), Multiple (4.5%) and Other/Unknown (3.2%). Participants in the highest SVI quartile were younger (18% aged 18-24 years), unmarried (36.3%), enrolled in WIC (34.2%), racial minorities (69.4%), and South King County residents (75.2%), compared with participants in the lowest three SVI quartiles.

PTB prevalence (%) across SVI quartiles and racial/ethnic groups are shown in **Table 2**. Overall, PTB prevalence increased across higher SVI quartiles— 6.2%, 6.8%, 7.5%, and 9.2% in Q1, Q2, Q3, and Q4, respectively. Birthing people of the Other/Unknown racial/ethnic category had the highest PTB prevalence (14.0%), followed by Black (10.1%) and Hispanic birthing people (8.9%). In general, PTB prevalence was highest in Q4, and lowest in Q1, for all racial/ethnic groups except Black birthing people. Among Black birthing people, PTB prevalence decreased with increasing SVI quartiles (12.1%, 10.6%, 10.2%, and 9.8% in Q1, Q2, Q3, and Q4, respectively). In contrast, a stepwise increase in PTB prevalence was observed, with increasing SVI quartiles, among birthing people in the Asian and Other/Unknown groups. White birthing people exhibited the lowest overall PTB prevalence (6.4%) and the least variation in PTB prevalence across SVI quartiles.

In the minimally adjusted Model 1, compared to participants in the reference quartile (Q1), the odds of PTB were higher among participants in Q2 (OR: 1.04, 95% CI: 0.96-1.13), Q3 (OR: 1.08, 95% CI: 1.00-1.17), and Q4 (OR: 1.17, 95% CI: 1.08-1.27) (trend p-value <0.001) (**Table 3**). In the partially adjusted Model 2, the corresponding ORs for Q2 (OR: 1.02, 95% CI: 0.94-1.11), Q3 (OR: 1.04, 95% CI: 0.96-1.13) and Q4 (OR: 1.07, 95% CI: 0.99-1.17) were attenuated and none reached statistical significance (trend p-value=0.166). Similarly, the

corresponding ORs for the fully adjusted model, Model 3, were further attenuated and did not reach statistical significance: Q2 (OR: 1.02, 95% CI: 0.94-1.10), Q3 (OR: 1.02, 95% CI: 0.94-1.11), and Q4 (OR: 1.07, 95% CI: 0.98-1.17) (trend p-value=0.107).

In race/ethnicity stratified models (**Table 4**), statistically significant positive associations were observed for Asian (OR: 1.24, 95% CI: 1.05-1.47) and Hispanic (OR: 1.39, 95% CI: 1.09-1.78) birthing people for Q4 in Model 1. In Model 2, non-significant positive SVI-PTB relationships were observed for Asian, Hispanic, Multiple, and Other/Unknown race/ethnicity groups (linear trend p-values of 0.112, 0.130, 0.809, and 0.374, respectively). Among White birthing people, the variation in odds of PTB risk across SVI quartiles was minimal (trend p-value=0.608). However, among Black birthing people, the SVI-PTB relationship was inverse and marginally insignificant (trend p-value=0.094). Specifically, among Black birthing people, the ORs were 0.84 (95% CI: 0.56-1.27) for Q2, 0.79 (95% CI: 0.54-1.16) for Q3, and 0.74 (95% CI: 0.51-1.07) for Q4. Results of stratified analyses using Model 3 were in general similar to what was reported for stratified analysis using Model 2 (described above). P-values obtained from likelihood ratio tests assessing interactions between SVI quartiles and race/ethnicity were statistically significant for Model 1 (p=0.011) but not for Model 2 (p=0.072) or Model 3 (p=0.108).

DISCUSSION

In the current study, we found potential evidence for associations of SVI with PTB. While this association was statistically significant in the model adjusting for King County Region, further adjustment for other covariates attenuated the relationships and associations were not statistically significant. Additionally, we found suggestive evidence for differences in SVI and PTB associations across racial/ethnic groups.

Previous studies using neighborhood-level indices of socioeconomic factors, such as the SVI, Neighborhood Deprivation Index (NDI), Index of Concentration at the Extremes (ICE), and Maternal Vulnerability (MVI), have reported increased odds of PTB among disadvantaged communities (11,12,16–19). One retrospective cohort study of 3.6 million U.S. singleton births in 2018 found that participants in the highest MVI quintile had an 18% increase in adjusted odds (OR:1.18, 95% CI: 1.07-1.29) of PTB compared to participants in the lowest quintile, with birth state treated as a fixed effect (17). Another cross-sectional study of 13 million live births in the U.S. between 2014 and 2018 found that participants in the highest MVI quartile had higher odds of PTB compared to participants in the lowest quartile (OR 1.41, 95% CI 1.39-1.43) (18). These findings were similar to the pattern we observed in Model 1.

One study that used the census-tract level SVI as an exposure found that higher overall SVI scores were associated with increased odds of PTB, and the largest magnitude of the associations were observed across the Socioeconomic Status (OR: 1.26, 95% CI: 1.08–1.46) and Household Characteristics (OR: 1.31, 95% CI: 1.13–1.52) themes (12). This retrospective cohort study included 15,364 patients at high risk of either spontaneous or medically indicated PTB and delivered singleton or twin gestations at the University of North Carolina Hospital System from April 2014 to January 2020. Another study found that participants in the highest quartile of county-level SVI had an increased risk of PTB, compared to participants in the lowest quartile (RR: 1.34, 95% CI: 1.31-1.36) (11). This cross-sectional study used data from the National Center for Health Statistics, encompassing U.S. live births (n= 51,044,482) between

2007 and 2019. While the observed estimates and associations were in general similar across studies, differences in the covariates included in the models and geographic context may limit comparisons of findings of these studies across each other and the current study.

In race-stratified models using 2000 U.S. census data, the Multilevel Modeling of Disparities to Explain Preterm Delivery (MODE-PTD) project, a collaboration among four universities and government health departments, aimed to identify specific domains linked to birth outcome disparities. It was found that non-Hispanic white women living in areas with high unemployment, low education, poor housing, low proportion of managerial occupations, and high poverty had increased odds of preterm birth. Similar associations were observed for non-Hispanic black women, but the effects were generally smaller (20). This finding aligns with another study that found a weaker association between NDI and PTB among non-Hispanic Black residents compared to non-Hispanic White residents in race-stratified models (19). Conversely, a study that used SVI found higher associations for Black residents in regression models that included Black race as a covariate (12). These divergent findings underscore the complexity of understanding the interplay between socioeconomic factors, race, and PTB.

There is no consensus “gold standard” index for evaluating neighborhood-level social determinants of health, and the role of different social determinants on PTB risk overall and among racial/ethnic groups are not fully understood. Proposed mechanisms through which the socioeconomic environment influences PTB focus mainly on the stress pathway. This pathway can be triggered by neighborhood events (e.g., eviction, crime, and police violence), resource availability (e.g., healthcare and nutrition), and the built environment (e.g., poverty and pollution) (20–22). These maternal stressors are believed to activate the stress pathway, leading to hypothalamic-pituitary-adrenal (HPA) dysregulation, environmental/epigenetic modifications, or immune and vascular dysfunction, such as bacterial vaginosis or elevated C-reactive protein levels – all of which have been related to pathogenesis of PTB (4). The relationship is further complicated by elements of structural racism that have all been conceptualized within multi-

causal frameworks linked to PTB: discriminatory practices in healthcare delivery, racial segregation, environmental racism, and the intergenerational effects of historical injustices, such as redlining (5,21,22). A more recent theory suggests that PTB is a cumulative biosensor of racial disparities (23). Although the present study did not yield statistically significant findings for SVI-race/ethnicity interactions, observed potential differences across racial/ethnic groups warrant further investigation.

While our study did not directly analyze SVI themes, we observed a potential inverse relationship between SVI and PTB among Black residents, suggesting a distinct relationship for this demographic that is different from our observation in other racial/ethnic groups. A possible explanation for this observation can be “racial clustering”. In a study assessing the impact of residential segregation on PTB, racial clustering emerged as a protective factor for Black residents, suggesting social ties and networks in ethnic enclaves might help mitigate negative neighborhood stressors on birth outcomes (24). In our sample, Black birthing people were more likely to reside in high SVI neighborhoods, which tend to cluster in the South Region of King County, WA. Our study indicates the need to study different mechanisms or indices for Black residents. Alternatively, it’s possible that a specific theme within the overall score, such as Socioeconomic Status, independently affects PTB risk for Black residents. As a result, the impact of Socioeconomic Status indicators might be hidden by the neighborhood's overall SVI score.

Several studies have identified distinct domains or themes as potential targets for policy intervention to mitigate PTB. For instance, the MODE-PTD project highlighted that high unemployment, low education, poor housing, a low proportion of managerial occupations, and high poverty were linked to increased PTB odds (20). Notably, the study also found that residential stability did not correlate with PTB in either group. This suggests that interventions focused on socioeconomic factors may be more effective in addressing PTB than those aimed solely at improving residential stability. Another study identified key contributors to PTB

disparities, noting that maternal education, marital status, source of payment for delivery, and hypertension in pregnancy were significant contributors to Black-White PTB disparities, based on a dataset representing U.S. registered births in 2016 (24). Furthermore, MVI research found that PTB rates were most strongly linked with the MVI themes of physical health and socioeconomic determinants, with Black residents being more exposed to harmful conditions affecting physical health, socioeconomic determinants, mental health and substance abuse, and physical environment (17,18). Together these findings suggest broad policy interventions focusing on improving maternal education and reducing poverty may have a “snowball effect” on birth outcomes in certain populations (12). Among Black residents, addressing neighborhood-level factors such as housing conditions, physical environment, employment opportunities, and access to healthcare could be particularly effective.

Current public health strategies to prevent PTB include: promotion of prenatal care utilization, identification and medical treatment of high-risk pregnancies, quality improvement initiatives to reduce nonmedically indicated PTB, prevention of unintended pregnancies through contraception access, and addressing the elevated risks associated with multiple gestations (25). While these strategies primarily target proximal causes of PTB, overemphasis on individual responsibility, such as health-seeking behaviors and medical intervention, can overshadow the systemic barriers, such as disparities in education and healthcare access. Furthermore, strategies for reducing health disparities should be culturally sensitive and context-specific, rather than a one-size-fits-all approach, which can exacerbate racial disparities. (26). Future studies on social vulnerability ought to stratify by additional racial/ethnic categories beyond Black-White comparisons to discern disparities and contextualize associations by relevant themes or domains. Such studies could better inform targeted policy interventions.

This study has several strengths. Our large sample size spanned all King County census tracts, providing a comprehensive census of its diverse birthing population. Using SVI alongside King County’s surveillance data provided an aggregate measure of various sociodemographic

indicators present in the community health indicators dashboard. These findings contribute to the growing body of literature supporting the expanded use of neighborhood-level indices for measuring social risk factors in relation to adverse birth outcomes. Lastly, to our knowledge, this is the first paper to assess the SVI-PTB relationship stratified by individual racial/ethnic categories. Adjustment for race without effect measure modification can mask racial disparities and perpetuate structural racism (27). In our study, we operationalize birthing person's race/ethnicity as a confounder for the primary aim and effect modifier for the secondary aim.

Our findings should be interpreted within the context of the study limitations. To account for group-level variation, researchers commonly employ either a fixed- or random-effects model. A limitation of fixed-effects models is that the fixed-effect may absorb too much variation in PTB outcomes, making the model more suitable for estimating effects within the sample rather than generalizing to a broader population. Consequently, this study may lack generalizability beyond King County. Additionally, given the observed collinearity between area-level SVI and sociodemographic characteristics (for example, residents living in high SVI census-tracts tend to have lower educational attainment), adjustments for these variables on the individual-level result may lead to an overadjustment and increase the risk of Type II error. Assessment of overall SVI score aggregates without analyzing SVI themes related to various dimensions of social vulnerability may obscure specific factors that independently impact PTB outcomes. As a result, the true relationship between social vulnerability factors and PTB outcomes may be misrepresented, leading to a form of misclassification. Specifically, the impact of certain social vulnerability themes on PTB outcomes might be inaccurately attributed or overlooked, which could explain the observed results among Black birthing people. Finally, exclusions based on missing data may introduce potential issues of selection bias in our analyses.

Our investigation of SVI in relation to PTB in King County's birthing population has potentially significant public health implications and raises important methodological considerations for future studies. In summary, we found suggestive positive associations

between SVI and PTB that varied across racial/ethnic groups. Future research should analyze SVI themes to better understand contributing factors in the multicausal social framework linked to PTB. Additionally, exploring potential effect modifications by race/ethnicity in different geographical contexts would further elucidate the SVI-PTB relationship in minority populations across the U.S. Neighborhood-level index measures such SVI can be used to inform local program or policy interventions, by using multi-level modeling to better understand social risk factors in vulnerable communities. Future studies in the areas of maternal and child health and social epidemiology are warranted to address the continued racial/ethnic disparities in PTB.

References

1. Dagher RK, Linares DE. A Critical Review on the Complex Interplay between Social Determinants of Health and Maternal and Infant Mortality. *Children*. 2022 Mar;9(3):394.
2. www.kingcounty.gov/chi [Internet]. 2024. Seattle & King County, Community Health Indicators.
3. Tippens K. King County Community Health Needs Assessment 2021/2022. Available from: <https://kingcounty.gov/en/legacy/depts/health/data/community-health-indicators/-/media/depts/health/data/documents/2021-2022-Joint-CHNA-Report.ashx>
4. Kramer MR, Hogue CR. What causes racial disparities in very preterm birth? A biosocial perspective. *Epidemiol Rev*. 2009;31:84–98.
5. Burris HH, Hacker MR. Birth outcome racial disparities: a result of intersecting social and environmental factors. *Semin Perinatol*. 2017 Oct;41(6):360–6.
6. Ncube CN, Enquobahrie DA, Albert SM, Herrick AL, Burke JG. Association of neighborhood context with offspring risk of preterm birth and low birthweight: A systematic review and meta-analysis of population-based studies. *Social Science & Medicine*. 2016 Mar 1;153:156–64.
7. Flanagan BE, Gregory EW, Hallisey EJ, Heitgerd JL, Lewis B. A Social Vulnerability Index for Disaster Management. *Journal of Homeland Security and Emergency Management* [Internet]. 2011 Jan 5 [cited 2023 Dec 31];8(1). Available from: <https://www.degruyter.com/document/doi/10.2202/1547-7355.1792/html>
8. Yap A, Laverde R, Thompson A, Ozgediz D, Ehie O, Mpody C, et al. Social vulnerability index (SVI) and poor postoperative outcomes in children undergoing surgery in California. *Am J Surg*. 2023 Jan;225(1):122–8.
9. Grabovschi C, Loignon C, Fortin M. Mapping the concept of vulnerability related to health care disparities: a scoping review. *BMC Health Serv Res*. 2013 Dec;13(1):94.

10. Saelee R, Chandra Murthy N, Patel Murthy B, Zell E, Shaw L, Gibbs-Scharf L, et al. Minority Health Social Vulnerability Index and COVID-19 vaccination coverage — The United States, December 14, 2020–January 31, 2022. *Vaccine*. 2023 Mar 17;41(12):1943–50.
11. Khan SS, Vaughan AS, Harrington K, Seegmiller L, Huang X, Pool LR, et al. US County–Level Variation in Preterm Birth Rates, 2007-2019. *JAMA Network Open*. 2023 Dec 8;6(12):e2346864.
12. Givens M, Teal EN, Patel V, Manuck TA. Preterm birth among pregnant women living in areas with high social vulnerability. *Am J Obstet Gynecol MFM*. 2021 Sep;3(5):100414.
13. Mendez DD, Scott J, Adodoadji L, Toval C, McNeil M, Sindhu M. Racism as Public Health Crisis: Assessment and Review of Municipal Declarations and Resolutions Across the United States. *Front Public Health*. 2021 Aug 11;9:686807.
14. Vital Records Forms | Washington State Department of Health [Internet]. [cited 2024 Feb 19]. Available from: <https://doh.wa.gov/licenses-permits-and-certificates/vital-records/forms-vital-records>
15. CDC SVI Documentation 2020 | Place and Health | ATSDR [Internet]. 2022 [cited 2023 Dec 1]. Available from: https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2020.html
16. Chambers BD, Baer RJ, McLemore MR, Jelliffe-Pawlowski LL. Using Index of Concentration at the Extremes as Indicators of Structural Racism to Evaluate the Association with Preterm Birth and Infant Mortality—California, 2011–2012. *J Urban Health*. 2019 Apr;96(2):159–70.
17. Salazar EG, Montoya-Williams D, Passarella M, McGann C, Paul K, Murosko D, et al. County-Level Maternal Vulnerability and Preterm Birth in the US. *JAMA Network Open*. 2023 May 25;6(5):e2315306.
18. Valerio VC, Downey J, Sgaier SK, Callaghan WM, Hammer B, Smittenaar P. Black-White disparities in maternal vulnerability and adverse pregnancy outcomes: an ecological

- population study in the United States, 2014–2018. *The Lancet Regional Health - Americas*. 2023 Apr 1;20:100456.
19. O'Campo P, Burke JG, Culhane J, Elo IT, Eyster J, Holzman C, et al. Neighborhood Deprivation and Preterm Birth among Non-Hispanic Black and White Women in Eight Geographic Areas in the United States. *American Journal of Epidemiology*. 2007 Oct 17;167(2):155–63.
 20. Messer LC, Vinikoor LC, Laraia BA, Kaufman JS, Eyster J, Holzman C, et al. Socioeconomic domains and associations with preterm birth. *Social Science & Medicine*. 2008 Oct 1;67(8):1247–57.
 21. Crear-Perry J, Correa-de-Araujo R, Lewis Johnson T, McLemore MR, Neilson E, Wallace M. Social and Structural Determinants of Health Inequities in Maternal Health. *Journal of Women's Health*. 2021 Feb;30(2):230–5.
 22. Kramer MS, Goulet L, Lydon J, Séguin L, McNamara H, Dassa C, et al. Socio-economic disparities in preterm birth: causal pathways and mechanisms. *Paediatric Perinatal Epidemiol*. 2001 Jul;15(s2):104–23.
 23. Burris HH, Lorch SA, Kirpalani H, Pursley DM, Elovitz MA, Clougherty JE. Racial disparities in preterm birth in USA: a biosensor of physical and social environmental exposures. *Archives of Disease in Childhood*. 2019 Oct 1;104(10):931–5.
 24. Thoma ME, Drew LB, Hirai AH, Kim TY, Fenelon A, Shenassa ED. Black–White Disparities in Preterm Birth: Geographic, Social, and Health Determinants. *American Journal of Preventive Medicine*. 2019 Nov;57(5):675–86.
 25. Shapiro-Mendoza CK. CDC Grand Rounds: Public Health Strategies to Prevent Preterm Birth. *MMWR Morb Mortal Wkly Rep [Internet]*. 2016 [cited 2024 May 9];65. Available from: <https://www.cdc.gov/mmwr/volumes/65/wr/mm6532a4.htm>

26. Thornton RLJ, Glover CM, Cené CW, Glik DC, Henderson JA, Williams DR. Evaluating Strategies For Reducing Health Disparities By Addressing The Social Determinants Of Health. *Health Affairs*. 2016 Aug;35(8):1416–23.
27. Swilley-Martinez ME, Coles SA, Miller VE, Alam IZ, Fitch KV, Cruz TH, et al. “We adjusted for race”: now what? A systematic review of utilization and reporting of race in *American Journal of Epidemiology* and *Epidemiology* , 2020–2021. *Epidemiologic Reviews*. 2023 Dec 20;45(1):15–31.

Table 1: Selected Sociodemographic Characteristics of Live Singleton Births in King County, WA, from 2018-2022, overall and by Social Vulnerability Index (SVI) Quartiles

Characteristic	SVI Quartile	Q1: 0- 0.25	Q2: 0.25 – 0.5	Q3: 0.5-0.75	Q4: 0.75 – 1
	89320 (100%)	19414 (21.7%)	20456 (22.9%)	21141 (23.7%)	28309 (31.7%)
Birth Person Age					
18-24 years	8564 (9.6%)	515 (2.7%)	1144 (5.6%)	1946 (9.2%)	4959 (17.5%)
25-34 years	52770 (59.1%)	10987 (56.6%)	12280 (60.0%)	12799 (60.5%)	16704 (59.0%)
35-39 years	2286 (25.6%)	6522 (33.6%)	5792 (28.3%)	5237 (24.8%)	5315 (18.8%)
40+ years	5120 (5.7%)	1390 (7.2%)	1240 (6.1%)	1159 (5.5%)	1331 (4.7%)
Educational Attainment					
Less than high school	6168 (6.9%)	220 (1.1%)	578 (2.8%)	1137 (5.4%)	4233 (15.0%)
High school graduate/GED	13385 (15.0%)	817 (4.2%)	1822 (8.9%)	2927 (13.8%)	7819 (27.6%)
Some college/Associate's degree	18155 (20.3%)	2231 (11.5%)	3640 (17.8%)	4486 (21.2%)	7798 (27.5%)
Bachelor's degree	27980 (31.3%)	7994 (41.2%)	7638 (37.3%)	6961 (32.9%)	5387 (19.0%)
Graduate/Professional degree	23632 (26.5%)	8152 (42.0%)	6778 (33.1%)	5630 (26.6%)	3072 (10.9%)
Infant Sex					
Female	47385 (49%)	9577 (49.3%)	9966 (48.7%)	10397 (49.2%)	13845 (48.9%)
Male	45535 (51%)	9837 (50.7%)	10490 (51.3%)	10744 (50.8%)	14464 (51.1%)
Marital Status					
Married	69848 (78.2%)	17656 (90.9%)	17642 (86.2%)	16517 (78.1%)	18033 (63.7%)
Not married	19472 (21.8%)	1758 (9.1%)	2814 (13.8%)	4624 (21.9%)	10276 (36.3%)
King County Region					
East	20519 (23.0%)	7586 (39.1%)	7130 (34.9%)	4669 (22.1%)	1134 (4.0%)
North	4455 (5.0%)	471 (2.4%)	1006 (4.9%)	2277 (10.8%)	701 (2.5%)
Seattle	25990 (29.1%)	9202 (47.4%)	5844 (28.6%)	5754 (27.2%)	5190 (18.3%)
South	38356 (42.9%)	2155 (11.1%)	6476 (31.7%)	8441 (39.9%)	21284 (75.2%)
Race/Ethnicity					
Asian	20723 (23.2%)	4866 (25.1%)	5577 (27.3%)	5464 (25.8%)	4816 (17.0%)
Black	7818 (8.8%)	332 (1.7%)	786 (3.8%)	1609 (7.6%)	5091 (18.0%)
Hispanic	12537 (14%)	1349 (6.9%)	1915 (9.4%)	2837 (13.4%)	6436 (22.7%)
Multiple	4005 (4.5%)	659 (3.4%)	783 (3.8%)	971 (4.6%)	1592 (5.6%)
Other/Unknown	2889 (3.2%)	255 (1.3%)	323 (1.6%)	599 (2.8%)	1712 (6.0%)
White	41348 (46.3%)	11953 (61.6%)	11072 (54.1%)	9661 (45.7%)	8662 (30.6%)
WIC Program Participation Status					
WIC participant	15057 (16.9%)	735 (3.8%)	1564 (7.6%)	3064 (14.5%)	9694 (34.2%)
Non-participant	74263 (83.1%)	18679 (96.2%)	18892 (92.4%)	18077 (85.5%)	18615 (65.8%)
Diabetes Status					
Pre-pregnancy diabetes	834 (0.9%)	105 (0.5%)	159 (0.8%)	176 (0.8%)	394 (1.4%)
No diabetes	88486 (99.1%)	19309 (99.5%)	20297 (99.2%)	20965 (99.2%)	27915 (98.6%)
Hypertension Status					
Pre-pregnancy hypertension	2101 (2.4%)	340 (1.8%)	436 (2.1%)	526 (2.5%)	799 (2.8%)
No hypertension	87219 (97.6%)	19074 (98.2%)	20020 (97.9%)	20615 (97.5%)	27510 (97.2%)
Kotelchuck Index					
>= 80%	61650 (69%)	13915 (71.7%)	14459 (70.7%)	14729 (69.7%)	18547 (65.5%)
<80%	27670 (31%)	5499 (28.3%)	5997 (29.3%)	6412 (30.3%)	9762 (34.5%)
Parity					

Nulliparous	41054 (46.0%)	9450 (48.7%)	10044 (49.1%)	10310 (48.8%)	11250 (39.7%)
Parous	48266 (54.0%)	9964 (51.3%)	10412 (50.9%)	10831 (51.2%)	17059 (60.2%)
Preterm Birth History					
History of PTB	2517 (2.8%)	360 (1.9%)	459 (2.2%)	583 (2.8%)	1115 (3.9%)
No PTB history	86803 (97.2%)	19054 (98.1%)	19997 (97.8%)	20558 (97.2%)	27194 (96.1%)
Smoking Status					
Non-smoker	87286 (97.7%)	19213 (99.0%)	20119 (98.4%)	20650 (97.7%)	27304 (96.5%)
Former smoker	672 (0.8%)	75 (0.4%)	125 (0.6%)	161 (0.8%)	311 (1.1%)
Smoked during pregnancy	1362 (1.5%)	126 (0.6%)	212 (1.0%)	330 (1.6%)	694 (2.5%)

Footnotes:

Abbreviations and definitions: SVI: Social Vulnerability Index, a composite measure developed by the Centers for Disease Control and Prevention (CDC) to measure social disadvantage based on community-level risk factors; PTB: Preterm Birth, defined as birth before 37 weeks of gestation; GED: General Educational Development test; WIC: Women, Infants, and Children program, a federal assistance program for low-income pregnant, birthing persons, infants and children up to age five.

Table 2: Prevalence Rate of Preterm Births (PTB), Overall and among Race/Ethnic Groups by Social Vulnerability Index (SVI) Quartiles (Q)

Race/ Ethnicity	Q1		Q2		Q3		Q4			
	Total	PTB n (%)	Total	PTB n (%)	Total	PTB n (%)	Total	PTB n (%)		
Overall	89320	6772 (7.58)	19414	1203 (6.20)	20456	1389 (6.80)	21141	1574 (7.45)	28309	2606 (9.21)
Asian	20723	1495 (7.21)	4866	297 (6.10)	5577	373 (6.69)	5464	395 (7.23)	4816	430 (8.93)
Black	7818	786 (10.05)	332	40 (12.05)	786	83 (10.56)	1609	164 (10.19)	5091	499 (9.80)
Hispanic	12537	1120 (8.93)	1349	96 (7.12)	1915	165 (8.62)	2837	228 (8.04)	6436	631 (9.80)
Multiple	4005	342 (8.54)	659	52 (7.89)	783	52 (7.15)	971	73 (7.52)	1592	161 (10.11)
Other/ Unknown	2889	405 (14.02)	255	20 (7.84)	323	20 (9.60)	599	80 (13.36)	1712	274 (16.00)
White	41348	2624 (6.35)	11953	698 (5.84)	11072	698 (6.15)	9661	634 (6.56)	8662	611 (7.05)

Footnotes:

Abbreviations and definitions: SVI: Social Vulnerability Index, a composite measure developed by the Centers for Disease Control and Prevention (CDC) to measure social disadvantage based on community-level risk factors; Total: sum of preterm and full-terms births by SVI Quartile and race/ethnicity; n: number of preterm births; %: prevalence of preterm birth.

Table 3: Associations of Social Vulnerability Index with Preterm Birth

SVI Quartile	Model 1: Minimally Adjusted OR (95% CI)	Model 2: Partially Adjusted OR (95% CI)	Model 3: Fully Adjusted OR (95% CI)
Q1	Ref	Ref	Ref
Q2	1.04 (0.96,1.13)	1.02 (0.94,1.11)	1.02 (0.94, 1.10)
Q3	1.08 (1.00, 1.17)	1.04 (0.96,1.13)	1.02 (0.94, 1.11)
Q4	1.17 (1.08,1.27)	1.07 (0.99,1.17)	1.07 (0.98, 1.17)
p-value	<0.001	0.093	0.107

Footnotes:

Abbreviations and definitions: SVI: Social Vulnerability Index, a composite measure developed by the Centers for Disease Control and Prevention (CDC) to measure social disadvantage based on community-level risk factors; OR: Odds Ratio; CI: Confidence Interval; p-value: trend test p-value when SVI quartile is treated as a continuous variable (e.g. 1-4).

1. Model 1 covariates: King County Region + birthing person's race/ethnicity
2. Model 2 covariates: birthing person's age, birthing person's race/ethnicity, educational attainment, infant sex, marital status, WIC status, and King County Region.
3. Model 3 covariates: birthing person's age, educational attainment, infant sex, marital status, birthing person's race/ethnicity, WIC status, parity, diabetes status, hypertension status, Kotelchuck index, preterm birth history, smoking status, and King County Region.

Table 4: Associations of SVI with PTB risk Stratified by Race/Ethnicity

Race/Ethnicity	SVI Quartile	Model 1: Minimally Adjusted OR (95% CI)	Model 2: Partially Adjusted OR (95% CI)	Model 3: Fully Adjusted OR (95% CI)
Asian	Q1 (ref)	ref	ref	ref
	Q2	1.05 (0.89, 1.23)	1.05 (0.90,1.23)	1.06 (0.90, 1.25)
	Q3	1.11 (0.95, 1.30)	1.09 (0.93,1.28)	1.09 (0.92, 1.28)
	Q4	1.24 (1.05, 1.47)	1.15 (0.96,1.37)	1.15 (0.96, 1.37)
	p-value	0.009	0.112	0.130
Black	Q1 (ref)	ref	ref	ref
	Q2	0.85 (0.57, 1.27)	0.84 (0.56,1.27)	0.93 (0.61, 1.41)
	Q3	0.82 (0.56, 1.19)	0.79 (0.54,1.16)	0.85 (0.57, 1.25)
	Q4	0.76 (0.52, 1.09)	0.74 (0.51,1.07)	0.83 (0.57, 1.22)
	p-value	0.106	0.094	0.296
Hispanic	Q1 (ref)	ref	ref	ref
	Q2	1.22 (0.94, 1.60)	1.17 (0.89,1.52)	1.15 (0.88, 1.50)
	Q3	1.14 (0.88, 1.47)	1.04 (0.80,1.35)	1.00 (0.77, 1.31)
	Q4	1.39 (1.09, 1.78)	1.23 (0.95,1.60)	1.20 (0.93, 1.56)
	p-value	0.007	0.130	0.181
Multiple	Q1 (ref)	ref	ref	ref
	Q2	0.88 (0.59, 1.32)	0.82 (0.55,1.23)	0.79 (0.52, 1.19)
	Q3	0.91 (0.62, 1.35)	0.82 (0.55,1.22)	0.80 (0.54, 1.20)
	Q4	1.17 (0.80, 1.70)	0.97 (0.65,1.44)	0.96 (0.65, 1.43)
	p-value	0.207	0.809	0.782
Oth/Unknown	Q1 (ref)	ref	ref	ref
	Q2	1.06 (0.58, 1.93)	1.00 (0.55,1.84)	0.99 (0.54, 1.82)
	Q3	1.38 (0.81, 2.38)	1.23 (0.71,2.15)	1.22 (0.69, 2.13)
	Q4	1.46 (0.86, 2.48)	1.22 (0.71,2.11)	1.19 (0.69, 2.07)
	p-value	0.072	0.374	0.431
White	Q1 (ref)	ref	ref	ref

Q2	1.02 (0.91, 1.14)	1.01 (0.91,1.13)	1.00 (0.89, 1.12)
Q3	1.08 (0.96, 1.21)	1.05 (0.93,1.18)	1.03 (0.91, 1.16)
Q4	1.12 (0.98, 1.27)	1.02 (0.90,1.16)	1.01 (0.89, 1.15)
p-value	0.057	0.608	0.751

Footnotes:

1. Abbreviations and definitions: SVI: Social Vulnerability Index, a composite measure developed by the Centers for Disease Control and Prevention (CDC) to measure social disadvantage based on community-level risk factors; OR: Odds Ratio; CI: Confidence Interval; p-value: trend test p-value when SVI quartile is treated as a continuous variable (e.g. 1-4).
2. Model 1 covariates: King County Region
3. Model 2 covariates: birthing person's age, educational attainment, infant sex, marital status, WIC status, and King County Region.
4. Model 3 covariates: birthing person's age, educational attainment, infant sex, marital status, WIC status, parity, diabetes status, hypertension status, Kotelchuck index, preterm birth history, smoking status, and King County Region.
5. P-values obtained from likelihood ratio tests assessing interactions between SVI quartiles and race/ethnicity were statistically significant for Model 1 (p=0.011) but not for Model 2 (p=0.072) or Model 3 (p=0.108).