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# Linking Social Vulnerability and Adverse Birth Outcomes in the Southeast United States

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## Abstract

**Background**: This study aims to explore the relationship between social vulnerability (SoVI) indicators (race/ethnicity, population structure, socioeconomic status, housing structure, and access/ functional needs) with low birth weight (LBW) and preterm delivery (PTD) rates across the Southeastern United States.

**Methods**: Annual low birth weight and premature birth rates for all counties were collected between 2000 and 2015. LBW and PTD were recoded into two categories below (0) and above (1) the annual national average for each year. Multinomial logistic regression (MLR) was employed to conduct regression analysis to investigate the relationship.

**Results**: Annual models resulted in a suite of different social vulnerability indicators were influential in predicting Low Birth Weight Rates and Preterm delivery across the SE United States from 2005-2015. Racial and ethnic variables were among the most frequent influential social vulnerability indicators of low birth weights. Like race and ethnicity, counties with low and medium house values have a higher likelihood of low LBW compared to counties with higher house values. Unlike LBW, race and ethnic characteristics influence PTD rates across the study area in different ways. Whereas LBW rates are driven up in counties with low/medium Hispanic populations compared to high percentage counties, PTD is more strongly associated with Black communities. Population structure and socioeconomic status indicators provide the most robust indication of counties more likely to have higher PTD than the national average.

**Conclusion**: Influential variables point toward a dire need to comprehensively understand the links between social vulnerability and LBW and PTD. Moving toward a comprehensive view of social vulnerability borne out of the hazard's literature provides a more robust understanding of the drivers of adverse birth outcomes.

**Keywords:** Preterm delivery, Low birth weight, Social vulnerability index.

## Introduction

### Adverse birth outcomes and links with social vulnerability

Social and biomedical research have both identified low birth weight and preterm delivery as critical risk factors for lifelong consequences, including poor health, cognitive deficits, and behavioral problems. Pregnancy length and birth weight have historically been used to evaluate a newborn's health quality [1]. A premature baby, defined as

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a live birth before completion of 37 weeks, is an essential marker of developmental complications throughout life [2]. Low birth weight (less than 5 pounds, 8 ounces, or 2500 grams) is strongly associated with a higher risk of infant mortality and morbidity [3]. The South Eastern United States provides an example of consistently elevated PTD and LBW compared to the national average. Above (national) average LBW and PTD across many Southeastern US counties make this an appropriate study area for undertaking summary level explanatory statistical analysis linking adverse birth outcomes to underlying socio-economic and demographic characteristics.

To date, most studies of this kind have only linked adverse birth outcomes to individual socio-demographic indicators such as poverty and access, which affect birth outcomes through underutilization of maternal health services, lower socioeconomic status, and limited health education [4]. Interactive effects between social indicators and birth outcomes have mainly focused on racial and ethnic disparities, concentrated poverty at the individual or community level, fragmented social support, and risky behaviors such as substance abuse, self-harm, unprotected sex, and having sex with multiple partners [5]. More recent health research on pregnancy outcomes investigates a broader definition of social predictors linked with adverse birth outcomes, especially LBW and PTD. Concentrated research on a more developed conceptualization of socioeconomic drivers linked to adverse birth outcomes stands to provide a more nuanced approach toward building interventions (programs, policies, strategies) for promoting healthy full-term births. This research is guided by one overarching research question: How are underlying social vulnerability indicators linked to adverse birth outcomes at the county level? Contrary to many previous studies analyzing influences on LBW and PTD together [5-10], this research measures social drivers' impact on LBW and PTD individually to build a more robust catalog of factors influencing these adverse birth outcomes across the Southeast United States.

Social vulnerability index (SoVI®) variables measure pre-existing community susceptibility to harm from external stressors such as natural or human-caused disasters or disease outbreaks that drastically affect lives and livelihoods [11-13]. The social vulnerability concept explains socioeconomic and demographic variations in a community's ability to prepare for, respond to, and rebound from environmental shocks and stressors [13]. Social vulnerability theory is built upon the understanding that human characteristics intervene between natural processes and the built environment to redistribute the social burden of disaster impacts, indicating that these social characteristics are independent of hazard type and magnitude [12,13]. Social vulnerability shares close conceptual and empirical ties with the concepts of health disparities and the social determinants of health [14].

Researchers characterize the determinants of adverse health outcomes using variables similar to those used in social vulnerability literature [15]. At the community level, health literature repeatedly examines healthcare access and vulnerability. The access is defined not only in terms of scarcity of services such as the lack of emergency services in rural areas, but also through insurance status, proximity to health providers, or family characteristics such as father's occupation, mother's height, maternal educational attainment, and the birth interval between pregnancies [16-20].

While many studies agree on the theoretical links between social determinants and health outcomes, few move beyond unidimensional analysis and toward building an understanding of the multidimensional nature of health (health needs and status and access) [21]. Though the frameworks for measuring health often separate concrete indicators of medical need and health access from social vulnerability indicators, some analyses simply tend to substitute them [22]. The study on the interaction between social vulnerability and natural systems measured ecological shocks' (social effects) or stressors on people and places [23]. However, no systematic effort has yet been identified to evaluate the possible impact of the full suite of social vulnerability indicators on adverse birth outcomes.

Inequalities in social vulnerability and associated outcomes may negatively affect the nutrition system, food security, education, healthcare utilization, and health status, often manifesting in higher risk/impacts on disadvantaged communities USA [5-9,24]. This paper seeks to explore how a broad suite of social vulnerability indicators, previously applied to environmental and disaster-related adverse outcomes, can independently predict summary level preterm births and low birth weights. Here, exploring how community social vulnerability characteristics can explain adverse birth outcomes between 2000 to 2015 provides a broader example of social indication of health disparities and may point to trends in linkages not previously known. This study's analysis of inequalities in adverse birth outcomes across the US Southeast generates a new perspective supporting effective health intervention and policy creation.

## Materials and Methods

### Study area

This study analyzes 12 states in the Southeast United States, including 928-935 counties (depending on the year analyzed) between 2000-2015. Southeastern states, characterized by widespread poverty, unemployment, lower educational attainment, and various other social vulnerability indicators, also have high preterm delivery and low birth weight rates. According to the United States Census (USA. Census Bureau QuickFacts: United States, 2021), all states included in this study except Virginia had lower per capita income than the national average and a higher percent of people living in poverty during 2014-2018 (Stats of the States - Low Birthweight Births, 2021) [24,25] .

### Data

**Birth outcome data:** Dependent variables in this analysis are annual low birth weight and premature birth rates for each county, calculated as the number of live singleton low birth weight and premature births divided by the total number of live singleton births year. The analysis unit is

county because birth outcome data for this large geographic area is only available at the county level. Part of the data on low birth weight and premature birth comes from publicly available data released by each states' department of health (Table 1).

Much of the data was not publicly available and required written request to several state health departments. County LBW and PTD were recoded into two categories - below (0) and above (1) the annual national rates (Table 2) for each birth outcome - in preparation for statistical analysis. Table 2 indicates the data on the national average and the range of LBW and PTD. However, birth outcome data was not available in all counties for all years. Therefore, there is a light inconsistency in the number of counties studied for LBW and PTD between 2000 to 2015.

**Social Vulnerability Predictor Data:** Table 3 provides the variable name, a description of each variable, and the general conceptual pillar from which social vulnerability may arise. While the SoVI creates a final index score for each enumeration unit in question, this work attempts to gain perspective on the individual input influence on adverse birth outcomes. Correlation was done across all three sets of SoVI variables (2000-2005, 2006-2010, and 2011-2015) to ensure that multicollinearity did not exist. Social vulnerability variables were standardized either as

**Table 1:** State birth outcome data sources.

| State | Resource | Source |
|---|---|---|
| Alabama | Alabama Department of Public Health | http://www.alabamapublichealth.gov/healthstats |
| Arkansas | Arkansas Department of Health | Direct Data Request |
| Florida | Florida Department of Health | http://www.flhealthcharts.com/charts/SearchResult.aspx |
| Georgia | Kids Count Data Center | https://datacenter.kidscount.org/data#GA/2/0/char/0 |
| Kentucky | Foundation for a Healthy Kentucky | http://www.kentuckyhealthfacts.org, www.healthy-ky.org |
| Louisiana | Louisiana Office of Public Health, Bureau of Family Health | Direct Data Request |
| Mississippi | Kids Count Data Center | https://datacenter.kidscount.org/ |
| North Carolina | North Carolina Department of Health and Human Services | https://schs.dph.ncdhhs.gov/data/databook/CD7B%20 Preterm%20births.html |
| South Carolina | South Carolina Department of Health and Environmental Control | http://scangis.dhec.sc.gov/scan/bdp/tables/birthtable.aspx |
| Tennessee | Tennessee Department of Health | https://www.tn.gov/health/health-program-areas.html |
| Virginia | Virginia Department of Human Resource Management | Direct Data Request |
| West Virginia | West Virginia Department of Health | Direct Data Request |

**Table 2:** National Average and Ranges of Low Birth Weights and Pre-Term Births (2000 – 2015).

| Year | National Average | | Low Birth Weights Classes/ Ranges | | Pre-Term Birth Classes/Ranges | | Source |
|---|---|---|---|---|---|---|---|
| | Low Birth Weight | Pre- Term Birth | Low | Hig | Low | Low | |
| 2000 | 7.6 | 11.6 | 0-7.5 | 7.6-24.1 | 0-11.5 | 11.6-34.4 | https://www.cdc.gov/nchs/data/nvsr/nvsr50/nvsr50_05.pdf |
| 2001 | 7.7 | 11.9 | 0-7.6 | 7.7-20.3 | 0.11.8 | 11.9-33.5 | https://www.cdc.gov/nchs/data/nvsr/nvsr51/nvsr51_02.pdf |
| 2002 | 7.8 | 12.1 | 0-7.7 | 7.8-20.4 | 0.12 | 12.1-29.2 | https://www.cdc.gov/nchs/data/nvsr/nvsr52/nvsr52_10.pdf |
| 2003 | 7.9 | 12.3 | 0-7.7 | 7.8-20.4 | 0.12.2 | 12.3-29 | https://wonder.cdc.gov/wonder/sci_data/natal/detail/type_txt/natal03/births03.pdf |
| 2004 | 8.1 | 12.5 | 0-8 | 8.1-28.6 | 0-12.6 | 12.7-27.8 | https://www.cdc.gov/nchs/data/hestat/prelimbirths04/prelimbirths04health. htm#figg |
| 2005 | 8.2 | 12.7 | 0-8.1 | 8.2-24 | 0-12.6 | 12.7-27.8 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |
| 2006 | 8.3 | 12.8 | 0-8.2 | 8.3-24.6 | 0-12.7 | 12.8-29.5 | https://www.cdc.gov/nchs/data/nvsr/nvsr56/nvsr56_07.pdf |
| 2007 | 8.2 | 12.7 | 0-8.1 | 8.2-28.4 | 0-12.6 | 12.7-37.1 | https://data.unicef.org/resources/data_explorer/ unicef_f/?ag=UNICEF&df=GLOBAL_DATAFLOW&ver=1.0&dq=.NT_BW_ LBW..&startPeriod=2005&endPeriod=2015 |
| 2008 | 8.1 | 12.3 | 0-8 | 8.1-30.8 | 0-12.2 | 12.3-30.8 | https://data.unicef.org/resources/data_explorer/ unicef_f/?ag=UNICEF&df=GLOBAL_DATAFLOW&ver=1.0&dq=.NT_BW_ LBW..&startPeriod=2005&endPeriod=2015 |
| 2009 | 8.1 | 12.1 | 0-8 | 8.1-30.7 | 0-12 | 12.1-26.2 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |
| 2010 | 8.1 | 11.9 | 0-8 | 8.1-35 | 0-11.8 | 11.9-26.3 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |
| 2011 | 8.1 | 11.7 | 0-8 | 8.1-30 | 0-11.6.7 | 11.7-35.7 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |
| 2012 | 7.9 | 11.7 | 0-7.8 | 7.9-28.6 | 0-11.4 | 11.5-30.6 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |
| 2013 | 8 | 11.3 | 0-7.9 | 8-30.8 | 0-11.2 | 11.3-26.9 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |
| 2014 | 8 | 9.5 | 0-7.9 | 7.9-21.1 | 0-9.4 | 9.5-24.6 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |
| 2015 | 8 | 9.6 | 0-8 | 8.1-22 | 0-9.5 | 9.6-26.2 | https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm, https://www. cdc.gov/nchs/pressroom/sosmap/preterm_births/preterm.htm |

**Table 3:** Social vulnerability predictor variable theoretical categories and statistical ranges by binned (low, medium, high) classification used in statistical analysis.

| Pillars | Variable Name | Description |
|---|---|---|
| Race/ Ethnicity | QBLACK | Percent Black |
| | QNATAM | Percent Native American |
| | QASIAN | Percent Asian |
| | QHISP | Percent Hispanic |
| Population Structure | MEDAGE | Median Age |
| | QKIDS | Percent Population under 5 years over 65 years of age |
| | QFEMALE | Percent Female |
| | QFHH | Percent Female Headed Households |
| | QFEMLBR | Percent Female Participation in Labor Force |
| | QFAM | Percent of Children living in 2 parent families |
| Socioeconomic Status | PPUNIT | People per Unit |
| | PERCAP | Per Capita Income |
| | QCVLUN | Percent Civilian Unemployment |
| | QED12LES | Percent with Less than 12th Grade Education |
| | QEXTRCT | Percent Employment in Extractive Industries |
| | QSERV | Percent Employment in Service Industry |
| | QPOVTY | Percent Poverty |
| | QRICH200K | Percent Households Earning over $200,000 annually |
| | MDGRENT | Median Gross Rent |
| | MDHSEVAL | Median Housing Value |
| Access and Functional Needs | QSSBEN | Percent Households Receiving Social Security Benefits |
| | QNOHLTH | Percent of population without health insurance |
| | QNRRES | Nursing Home Residents Per Capita |
| | QESL | Percent Speaking English as a Second Language with Limited English Proficiency |
| | QNOAUTO | Percent of Housing Units with No Car |
| Housing Structure | QUNOCCHU | Percent Unoccupied Housing Units |
| | QRENTER | Percent Renters |
| | QMOHO | Percent Mobile Homes |

percentages, per capita, means or medians (depending on how the data was originally collected) and then recoded into three categories using standard deviations (<-.5 = Low -.5 = Medium, and >.5 = High). In this way, a county can have a low class for some variables and high classes for other variables.

## Analytic strategy

Application of multinomial logistic regression (MLR) allowed consideration of a two-category dependent variable in reference to a large set of three-category predictor variables. The MLR model is an extension of binary logistic regression, producing two sets of coefficients ($e^{\beta}$) expressed as odds ratios. MLR can be applied when underlying variable assumptions cannot be met for Ordinary Least Squares (OLS) regressions. Whereas ratio or interval scales provide a sound basis for a more robust OLS model, these assumptions tend to disintegrate in a regression model with categorical outcome data. Moreover, MLR has alternative assumptions like the non-perfect separation across groups of the outcome variables, which prevents unrealistic coefficients and exaggerated effect sizes [26].

An MLR model identified influential relationships between social vulnerability variables and adverse birth outcomes. Coefficients depicted the association between the social vulnerability variables and the odds of a county having lower low birth weight and premature birth rates than the odds of that same county having higher rates of low birth weight and premature birth. Further, while OLS $R^2$ indicates the variability in the dependent variable explained by the model, Psuedo $R^2$ (resulting from MLR) is neither directly comparable to the R-squared for OLS models nor can it be interpreted same fashion as $R^2$. Rather, pseudo-R-squared is a relative measure of how well the model explains the data. The following value classifications for our pseudo $R^2$ values were utilized: <.3 (no or very weak model explanation), .3-.5 (weak model explanation),.5.1-.7 (moderate model explanation), and >.7 (strong model explanation), adapted from Moore and Kirkland (2007). The MRL model identifies individual variable influence on adverse birth outcome categories (low and high). The results of the beta coefficient cardinality, odds, ratios, and significance level enable a straightforward way of understanding how social variables directly influence outcomes in a controlled manner. While trends in variable interactions across all years would clearly indicate key drivers, this analysis primary aim is a more holistic understanding of all interactions. Annual MLR model runs controlling for all other social vulnerability variables enables identification of individual variable interactions year-to-year.

## Results

Table 4 provides some basic socio-economic data comparing the study area states to national averages for several social vulnerability indicators. Bolded values indicated states that are have more vulnerable populations than the US average for any given indicator. Indicators such as median household income, poverty rate, age dependent population (people under-five and over 65 years), and the percent of the population without health insurance show widespread social inequality in the states studied compared to national rates.

**Table 4:** Selected social vulnerability characteristics for Southeastern states in comparison to US Averages.

| United States | Persons under 5 years | Persons 65 years and over | Black or African American | With a disability | Persons without health insurance | Persons in poverty | Median household income | Per capita income in past 12 months |
|---|---|---|---|---|---|---|---|---|
| | 6.10% | 16.00% | 13.40% | | 10.00% | 11.80% | $60,29 | $32,62 |
| Alabama | 6.00% | 16.90% | 26.80% | 11.60% | 12.00% | 16.80% | $48,48 | $26,84 |
| Arkansas | 6.30% | 17.00% | 15.70% | 12.50% | 9.80% | 17.20% | $45,72 | $25,63 |
| Florida | 5.40% | 20.50% | 16.90% | 8.60% | 16.00% | 13.60% | $53,26 | $30,19 |
| Georgia | 6.20% | 13.90% | 32.40% | 8.70% | 15.70% | 14.30% | $55,67 | $29,52 |
| Kentucky | 6.20% | 16.40% | 8.40% | 13.10% | 6.70% | 16.90% | $48,39 | $26,94 |
| Louisiana | 6.60% | 15.40% | 32.70% | 11.00% | 9.30% | 18.60% | $47,94 | $27,02 |
| Mississippi | 6.20% | 15.90% | 37.80% | 11.80% | 14.40% | 19.70% | $43,56 | $23,43 |
| North Carolina | 5.90% | 16.30% | 22.20% | 9.50% | 12.70% | 14.00% | $52,41 | $29,45 |
| South Carolina | 5.80% | 17.70% | 27.10% | 10.40% | 12.70% | 15.30% | $51,01 | $27,98 |
| Tennessee | 6.00% | 16.40% | 17.10% | 11.10% | 12.00% | 15.30% | $50,97 | $28,51 |
| Virginia | 6.00% | 15.40% | 19.90% | 8.00% | 10.20% | 10.70% | $71,56 | $37,76 |
| West Virginia | 5.30% | 19.90% | 3.60% | 14.10% | 7.90% | 17.80% | $44,92 | $25,47 |

Figure 1 illustrates annual average low birth weights and pre-term birth rates in the Southeast United States (2000-2015). Low birth weight rates (Figure 1A) displayed here using CDC's National Center for Health Statistics classification scheme show medium high (>9.6%) and high (>10.8%) low-birth weight rates across 38.8% of Southeastern Counties (Cdc.org, 2021) [25].

Pre-Term Birth Rates (Figure 1B) displayed here using the March of Dimes Report Card classification scheme show that a majority of counties (74.1%) have either a "D" or "F" rating (March of Dimes.org, 2020) [27]. In combination, 34.5% counties have both medium-high or higher low birth rate AND a "D" or "F" according to March of Dimes birth report card. These facts make the southeast US ideal for investigations into relationships between these adverse outcomes and underlying social conditions. Identifying more nuanced relationships between adverse birth outcomes and underlying social vulnerabilities can only help policymakers, and program developers build better interventions into the future.

Categorizing numerous socio-economic variables by theoretically linked "pillar" provides a reference for understanding how each is individual variable is linked with social vulnerability. Grouping these variables into conceptual pillars supports this more detailed assessment of links between vulnerability and outcomes that would be likely be otherwise lost due to the large number of model predictor variables.

Understanding links between social vulnerability and adverse birth outcomes for each year (2000-2015) required 15 MLR models for each outcome measure (LBW and PTD). Although some threads of similar socioeconomic influence are seen across each annual model run, there are many instances where adverse birth outcome drivers vary year to year. Furthermore, social variables are grouped according to their theoretical link to vulnerability, known here as vulnerability "Pillars." These pillars categorize the indicators into concepts, each pillar showing the underlying dimensions of the SoVI index [28].

Across all models, the pseudo-R-square values range from .104 to .304, indicating low to moderate overall model fit across the years and outcomes. The data has a slightly higher fit for LBW in 2009 (Nagelkerke Psuedo $R^2$ of .304) than other years; however, generally, lower pseudo-R-squared values suggest that there are many additional variables besides social vulnerability driving adverse birth outcomes. However, because the intent of this analysis is to build an understanding of individual social vulnerability characteristic influence on adverse birth outcomes rather than developing a complete model for predicting birth outcomes, such Nagelkerke Psuedo $R^2$ value are expected. In this way, individual variable odds ratios and associated significance produced by MLR suggest that several social variables each year have a substantial influence on adverse birth outcomes. Tables 5A, B, and C and 6A, B, and C show MLS model information, including number of inputs, Chi-Square significance, Nagelkerke Psuedo $R^2$ for each year/model, and those social vulnerability variables with a significant influence on adverse birth outcomes.

## Low birth weight models

Many social vulnerability indicators provide a significant and robust influence on low-birth-weight rates across the study area (Tables 5A, B, and C). Significant numbers of social vulnerability indicators were influential in predicting Low Birth Weight Rates across the SE United States from 2005-2015. While some of these social indicators were only significant in a limited number of models runs, several characteristic groupings (low, medium, high percentages) were predictive in most models (i.e. Low Hispanic Populations was a significant and robust indicator in 75% of models, mobile homes (50% of models), educational attainment (56% of models), female-headed households (50% of models), and renters (50% of models) (Tables 5A, B, and C).

Racial and ethnic variables were among the most frequent influential social vulnerability indicators of low birth weights in the Southeast United States between 2000-2015 when comparing across model years (Tables 5A, B, and

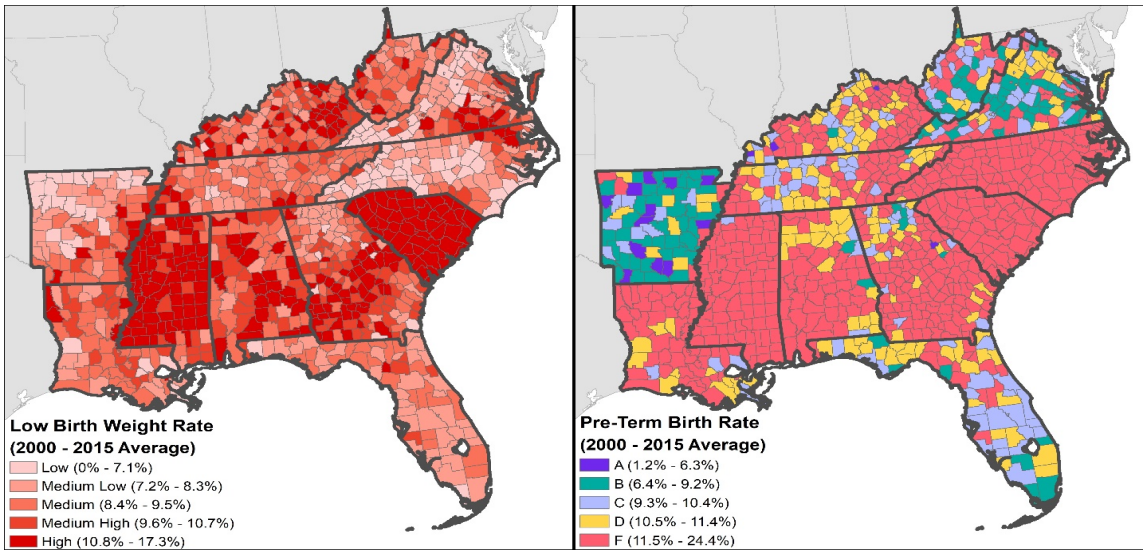


**Figure 1:** County level A. Low Birth Weight Rates, and B. Pre-Term Birth Rates in the 12-state Southeastern US study area.

**Table 5A:** Model outputs showing negative and positive influences of social indicators on low birth weight rates in the Southeast United States (2000 – 2005).

| Social Vulnerability Concepts/Pillars | Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| | Nagelkerke Pseudo R2 | 0.14 | 0.104 | 0.228 | 0.186 | 0.208 | 0.208 |
| | Model Significance | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Number of Counties in model | 928 | 928 | 928 | 928 | 928 | 928 |
| A - Negative Influences - Variables increasing (compared to high percentage of same variable) the likelihood of Low Birth Rates above the national average (Percentage of Models/Years Influential) | | | | | | | |
| Race/Ethnicity | Low (< 0.6%) Hispanic Population | 48%* | | 53%* | 54%* | | 64%*** |
| | Medium (0.61 - 4.33%) Hispanic Population | | | | | | 53%*** |
| Population Structure | Low (< 11.96%) Population > 65 Years of age | 64%* | 64%* | | 44%* | | |
| | Medium (11.92 - 15.52%) Population > 65 Years of age | 44%* | 48%* | 45%* | | 54%** | |
| | Low (< 6.02%) Population under 5 years of age | | | 74%**** | | | 67%*** |
| | Low (<15.45%) Female Headed Households | | 45%* | | | | |
| Socioeconomic status | Low (< $14,798) Per Capita Income | | | 33%*** | | | |
| | Medium ($14,581-$17,839) Per Capita Income | | | 58%** | | | |
| | Medium (14.02-20.18%) in Poverty | | | 60%*** | | | |
| | Low (< 12.6%) Employment in Extractive Industries | | 49%* | | | | |
| | Low (< $66,000) House Value | | | 61%* | 60%* | 66%** | 57%* |
| | Medium($84500-$88900) House Value | | | 48%* | | 50%* | |
| B - Positive Influences - Variables decreasing (compared to high percentages of the same variable) the likelihood of Low Birth Rates above the national average (Percentage of Models/Years Influential) | | | | | | | |
| Race/Ethnicity | Medium (10.52-29.6%) Black Population | 79%* | 79%* | | | 89%* | |
| Population Structure | Low (< 49.89%) Female Population | | 86%* | 29%*** | | | |
| | Medium (49.51 < 51.95%) Female Population | | 72%** | 55%* | | | |
| | Low (< 15.45%) Female Headed Households | | | 29%* | 11%* | | 28%* |
| Socioeconomic status | Medium (25.48-33.09% ) with Less than 12th Grade Education | | | 66%* | 59%* | 69%** | 57%* |
| | Medium ($37.72-$56.79) Median Gross Rent | 18%* | | | | | |
| | Low (< 4.04%) Households Earning over $200,000 annually | | | 60%**** | | | |
| | Medium (4-7.29%) Households Earning over $200,000 annually | | | 42%* | | | |
| Housing Structure | Medium (17.37-27.15%) Mobile Homes | | | | | 62%** | |
| | Medium ( 18.34-25.13%) Renters | | | 77%* | 89%** | 94%** | |
| Access and functional needs | Low (< 37.5%) Speaking English as a Second Language with Limited English Proficiency | 16%*** | 68%** | | | | |
| | Medium (37.72- 56.79%) Speaking English as a Second Language with Limited English Proficiency | 62%* | | | | | |
| | Low (< 10.27%) Households Receiving Social Security Benefits | | | 65%* | | | |
| Variable Significance: .05*, .01**, .005***, .001**** | | | | | | | |

**Table 5B:** Model outputs showing negative and positive influences of social indicators on low birth weight rates in the Southeast United States (2006 – 2010).

| Social Vulnerability Concepts/Pillars | Year | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| | Nagelkerke Pseudo R2 | 0.282 | 0.276 | 0.273 | 0.304 | 0.261 |
| | Model Significance | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Number of Counties in model | 932 | 932 | 932 | 932 | 932 |
| A - Negative Influences - Variables increasing (compared to high percentage of same variable) the likelihood of Low Birth Rates above the national average | | | | | | |
| Race/Ethnicity | Medium (0.21-1.58%) Asian Population | | | | 57%* | |
| | Medium (0- 1.29%) Native American Population | 77%** | 64%* | 54%* | 22%*** | 54%* |
| | Low (< 1.88%) Hispanic Population | | | 66%** | 55%* | 62%** |
| | Medium (1.90-7.23%) Hispanic Population | | | 42%* | 45%* | 48%* |
| | Medium (60.71-71.75%) Percent of Children Living in 2-parent Families | | 34%* | | | |
| | Low(< 45.95%) Percent Female Participation in Labor Force | | | 43%* | | |
| Socioeconomic status | Medium ($95000-$137500%) House Value | 54%* | | 48%* | | |
| Housing Structure | Low(< 24.69%) Mobile Homes | 59%** | | 46%* | 45%* | |
| | Medium (24.77-59.36%) Mobile Homes | 36%* | | | 46%** | |
| Access and functional needs | Low (< 0.16%) Speaking English as a Second Language with Limited English Proficiency | | | | | 42%* |
| B - Positive Influences - Variables decreasing (compared to high percentages of the same variable) the likelihood of Low Birth Rates above the national average (Percentage of Models/Years Influential) | | | | | | |
| Race/Ethnicity | Low (< 11.46%) Black Population | | | 81%** | | |
| | Medium (11.63-30.59%) Black Population | | | 12%* | | |
| Population Structure | Low (< 2.42%) People per Unit | | | | | 63%* |
| | Low (< 49.27%) Female Population | | | 28%* | 26%* | |
| | Medium (49.30-51.71%) Female Population | | | 62%* | | |
| | Low (< 12.31%) Female Headed Households | 42%** | 63%** | | 30%*** | 47%* |
| | Medium (12.33-16.65%) Female Headed Households | 78%** | 36%* | | 97%*** | |
| Socioeconomic status | Low (< 18.46%) with Less than 12th Grade Education | 18%* | 10%* | 7%* | 13%* | 83%** |
| | Medium (18.47-25.15%) with Less than 12th Grade Education | 80%* | 88%** | 14%** | 57%** | 61%* |
| | Low (< 25.57%) Civilian Unemployment | | 65%** | 80%** | 34%* | |
| | Medium (25.62-33.21%) Civilian Unemployment | | | 84%* | | |
| | Low (< 2.12%) Employment in Extractive Industries | | | | | 73%* |
| | Low (< 15.50%) Employment in Service Industry | | 85%* | 65%* | 63%* | |
| | Medium (15.51-19.23%) Employment in Service Industry | | 84%** | | 73%* | |
| Housing Structure | Low (< 20.34%) Renters | | | | | 43%* |
| | Medium (20.37-27.79%) Renters | | | | | 80%* |
| Access and functional needs | Low (< 0.33%) Speaking English as a Second Language with Limited English Proficiency | | 47%** | | | |
| | Low (< 30.86%) Households Receiving Social Security Benefits | 22%* | | | | |
| | Medium (18.14-21.93%) population without health insurance | | | | | 87%* |
| Variable Significance: .05*, .01**, .005***, .001**** | | | | | | |

**Table 5C:** Model outputs showing negative and positive influences of social indicators on low birth weight rates in the South east United States (2011 – 2015).

| Social Vulnerability Concepts/ Pillars | Year | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| | Nagelkerke Pseudo R2 | 0.24 | 0.219 | 0.265 | 0.274 | 0.297 |
| | Model Significance | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Number of Counties in model | 935 | 935 | 935 | 935 | 935 |
| A - Negative Influences - Variables increasing (compared to high percentage of same variable) the likelihood of Low Birth Rates above the national average | | | | | | |
| Race/Ethnicity | Medium (0-1.23%) Native American | 61%* | | | | 58%* |
| | Low (< 1.92%) Hispanic Population | 66%** | 51%* | 56%* | 64%* | 62%* |
| | Medium (1.94-7.43%) Hispanic Population | 51%* | | | 51%* | 54%* |
| Population Structure | Medium (20.65-24.21%) Population < 5 and > 65 Years | | | | 61%* | |
| Socioeconomic status | Low (< $89900%) House Value | 55%* | | | | |
| | Medium ($90500-$150800%) House Value | | 60%* | 63%* | | |
| Housing Structure | Low (< 13.65%) Mobile Homes | 54%* | 59%** | 63%*** | 63%** | 53%* |
| | Medium (13.67-24.053%) Mobile Homes | | | 38%* | | 45%* |
| B - Positive Influences - Variables decreasing (compared to high percentages of the same variable) the likelihood of Low Birth Rates above the national average | | | | | | |
| Population Structure | Low (< 2.45%) People per Unit | | 74%* | | | |
| | Low (< 49.73%) Female Population | 21%** | | | | |
| | Low (< 11.93%) Female Headed Households | | 35% | | 49%* | |
| Socioeconomic status | Medium ($592-$775%) Median Gross Rent | | 23%*** | | | |
| | Low (<29.04%) Civilian Unemployment | 14%* | | 41%* | 16%*** | 3%** |
| | Low (< 2.150%) Employment in Extractive Industries | 76%* | | 90%* | | |
| | Medium (2.156-6.24%) Employment in Extractive Industries | 61%* | | 87%* | | |
| Housing Structure | Low (< 20.49%) Renters | | 79%** | | | |
| | Medium (20.51-28.23%) Renters | | 44%*** | 66%* | 66%* | 18%** |
| Access and functional needs | Medium (15.61-21.39%) Speaking English as a Second Language with Limited English Proficiency | | | 59%* | | |
| | Low (< 33.94%) Households Receiving Social Security Benefits | | 46%* | 45%* | 67%** | |
| | Medium (33.96-41.22%) Households Receiving Social Security Benefits | 58%* | 63%* | 85%* | | |
| Variable Significance: .05*, .01**, .005***, .001**** | | | | | | |

C). Counties have an increased likelihood (+42% - +66% likelihood) of higher low-birth-weight rates when they have low and medium percentages of Hispanic populations and (+25% - +77%) when a county had at least medium percentages of Native American populations compared to higher percentages. Similarly, between 2000 – 2005, counties with low and medium-low percentages are age-dependent populations (under 5 or over 65 years) had increased likelihood (+44% + 66%) of higher LBW rates than counties with higher percentages of age-dependent populations (Figure 5). These results indicate a protective effect associated with higher populations of these racial and ethnic populations. Further, although a suite of socioeconomic indicators shows the influence on LBW rates in some years, per-capita income (a routinely used indicator) was a less robust indicator of LBW rates across the study area in comparison to housing value. Here, house value provides the most consistent wealth indicator of LBW across many years. Like race and ethnicity, counties with low and medium house values have a higher likelihood of low LBW compared to counties with higher house values.

Several social vulnerability indicators show a substantial and significant positive influence on LBW in each model run in each of the three model runs. Each of these "positive influences" points out that counties with the highest percentages across these social vulnerability indicators are more likely to have higher LBW rates. Namely, counties with low and medium percent Black populations, females, female-headed households, educational attainment, unemployment, extractive and service employment, renters, limited English proficiency, and social security beneficiaries tended to have lower LBW rates in comparison to counties with high percentages of these characteristics.

## Preterm birth models

A considerable number of social vulnerability variables were influential in one or more PTD models for the SE United States (Tables 6A, 6B, and 6C). Like LWB models, several variables were only significantly influential in one or few models, included the Percentage of People Living in Poverty, which was only a significant predictor in the 2000 and 2004 models. Several groupings of variables, including low/medium percentage black populations (81% of models), low/medium gross rent (43% of models), and low/medium nursing home residents per capita (37% of models), had a significant relationship with PTD rates when comparing across all model years.

Unlike LBW, race and ethnic characteristics influence PTD rates across the study area in different ways. Whereas LBW rates are driven up in counties with low/medium Hispanic populations compared to high percentage counties, PTD is more strongly associated with higher percentages of Black populations. Population structure and socioeconomic status indicators provide the most robust indication of counties more likely to have higher PTD than the national average. Although no consistent indictor of PTD was discovered across all models (years), higher rates were more heavily influenced by low and medium gross rent across many years (models).

**Table 6A:** Model outputs showing negative and positive influences of social indicators on pre-term birth rates in the Southeast United States (2000 – 2005).

| Social Vulnerability Concepts/Pillars | Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| | Nagelkerke Pseudo R2 | 0.201 | 0.187 | 0.169 | 0. 212 | 0.224 | 0.256 |
| | Model Significance | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Number of Counties in model | 984 | 984 | 984 | 984 | 984 | 984 |
| A - Negative Influences - Variables increasing (compared to a high percentage of the same variable) the likelihood of preterm birth Rates above the national average | | | | | | | |
| Race/ Ethnicity | Low (< 0.55%) Hispanic | | | | 53%* | | |
| | Low (< 0.22%) Asian | | | | 51%* | | |
| | Medium (0.23-0.87%) Asian | | | | 50%** | | |
| Population Structure | Low (< 0.22%) Population > 65 Years | | 64%** | 69%*8 | | 63%* | |
| | Medium (0.23-0.87%) Population > 65 Years | | 42%* | 48%* | | | |
| | Medium (2.47-2.61%) People per Unit | 50%** | 43%** | 38%* | | | |
| Socioeconomic status | Medium (14.02-20.18%) Poverty | 51%* | | | | | |
| Housing Structure | Low (<18.31%) Renters | | | | | 63%** | |
| | Medium (17.37-27.15%) Mobile Homes | | | | | | 35%* |
| Access and Functional Needs | Low (< 3 %) Speaking English as a Second Language with Limited English Proficiency | | | | | | 97%* |
| | Medium (10.37-13.12%) Households Receiving Social Security Benefits | 42%* | | | | | |
| B - Positive Influences - Variables decreasing (compared to a high percentage of the same variable) the likelihood of Preterm Birth Rates above the national average | | | | | | | |
| Race/ Ethnicity | Low (< 10.24%) Black Population | 19%** | 80%** | 76%** | | 40%** | 47%**** |
| | Medium (10.25-29.6%) Black Population | 68%* | | | | | |
| Population Structure | Low (<49.83%) Female Population | 40%** | | 75%* | | 37%** | 31%** |
| | Low (< 45.26%) Percent Female Participation in Labor Force | 33%* | | | | | |
| Socioeconomic status | Low (< 12.57%) Employment in Service Industry | | | | | | 59%* |
| | Medium (14.02-20.18%) Poverty | | | | | 69%* | |
| Housing Structure | Medium (18.34-25.13%) Renters | | | | | 72%* | |
| | Low (< 17.31%) Mobile Homes | 67%* | | 83%* | | | |
| Access and functional needs | Medium (10.37-13.12%) Households Receiving Social Security Benefits | | 43%* | | | | |
| | Low (<10.35%) Nursing Home Residents Per Capita | | 44%* | | 39%* | 50%** | 49%** |
| | Low (<25.43%) Speaking English as a Second Language with Limited English Proficiency | 76%** | 94%** | 59%* | | | 85%*** |
| | Medium (25.48-33.09%) Speaking English as a Second Language with Limited English Proficiency | 42%* | 51%* | 73%** | | 48%* | 53%* |
| Variable Significance: .05*, .01**, .005***, .001**** | | | | | | | |

**Table 6B:** Model outputs showing negative and positive influences of social indicators on pre-term birth rates in the Southeast United States (2006 – 2010).

| Social Vulnerability Concepts/Pillars | Year | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| | Nagelkerke Pseudo R2 | 0.223 | 0.23 | 0.179 | 0.17 | 0.143 |
| | Model Significance | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Number of Counties in model | 985 | 985 | 985 | 985 | 985 |
| A - Negative Influences - Variables increasing (compared to a high percentage of the same variable) the likelihood of preterm birth Rates above the national average | | | | | | |
| Race/ Ethnicity | Low (< 0.21%) Asia Population | | | | 51%* | |
| | Medium (0.22-1.58%) Asian Population | | | | 41%* | |
| Population Structure | Low (< 19.58%) Population< 5 and > 65 Years | | 12%*** | | 47%*** | |
| Socioeconomic status | Medium (15.67-22.23%) Poverty | | | | | |
| | Low (< $525%) Gross Rent | 72%** | | 75%* | 14%*** | |
| | Medium ($575-$675%) Gross Rent | 64%* | | 71%* | 18%** | 60%* |
| | Low (< 15.50%) Employment in Service Industry | 67%* | | | | 59%* |
| | Medium (15.51-19.23%) Employment in Service Industry | 57%* | | | | |
| B - Positive Influences - Variables decreasing (compared to a high percentage of the same variable) the likelihood of Preterm Birth Rates above the national average | | | | | | |
| Race/ Ethnicity | Low (< 11.46%) Black Population | 9%** | 57%** | 18%** | 40%** | |
| | Medium (11.63-30.59%) Black Population | 57%* | 86%* | | | |
| Population Structure | Low (<37.3%) Median Age | 17%**** | | 84%*** | | 50%*** |
| | Low (< 49.27%) Female Population | | 75%* | 74%* | | |
| | Low (< 12.31%) Female Headed Households | 39%* | | | | |
| | Low (< 45.95%) Percent Female Participation in Labor Force | | | 55%* | | |
| | Low (<2.42%) People per Unit | 69%** | | | | |
| Socioeconomic status | Low (< 2.12%) Employment in Extractive Industries | | 73%* | | | |
| | Medium (2.14-6.12%) Employment in Extractive Industries | | 48%* | | | |
| | Low (<15.50%) Employment in Service Industry | | | | | |
| | Low (< $17,155.59) Per Capita Income | | | 30%* | | |
| | Medium (< $17,183.57-$22,454.016) Per Capita Income | | | 78%** | | |
| Housing Structure | Low (2.34%) Renters | | | | 82%* | |
| | Low (< 14.39%) Mobile Homes | 90%* | | | | |
| Access and functional needs | Low (< 041%) Nursing Home Residents Per Capita | 37%**** | | | | |
| | Low (<0. 165%) Speaking English as a Second Language with Limited English Proficiency | | | | | 48%* |
| | Medium (0.166-0.339%) Speaking English as a Second Language with Limited English Proficiency | | | 49%* | | 54%* |
| Variable Significance: .05*, .01**, .005***, .001**** | | | | | | |

**Table 6C:** Model outputs showing negative and positive influences of social indicators on pre-term birth rates in the Southeast United States (2011 – 2015).

| Social Vulnerability Concepts/Pillars | Preterm Birth Rate | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| | Nagelkerke Pseudo R2 | 0.23 | 0.187 | 0.182 | 0.122 | 0.138 |
| | Model Significance | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Number of Counties | 977 | 977 | 977 | 977 | 977 |
| A - Negative Influences - Variables increasing (compared to a high percentage of the same variable) the likelihood of preterm birth Rates above the national average | | | | | | |
| Race/ Ethnicity | Low (< 1.92%) Hispanic Population | | 50%* | | | |
| Population Structure | Low (< 20.64%) Population under 5 and > 65 Years | | 45%* | | | |
| Socioeconomic status | Low (< $591%) Gross Rent | 84%** | | 70%* | 75%** | |
| | Medium ($592-$775%) Gross Rent | 85%*** | | 64%* | 75%*** | |
| | Low (< 15.60%) with Less than 12th Grade Education | | | | 49%* | |
| Housing Structure | Low (< 13.50%) Unoccupied Housing Units | 37%* | | 38%* | | |
| | Medium (13.53- 21.41%) Unoccupied Housing Units | 68%* | | 72%* | | |
| B - Positive Influences - Variables decreasing (compared to a high percentage of the same variable) the likelihood of Preterm Birth Rates above the national average | | | | | | |
| Race/ Ethnicity | Low (< 10.51%) Black Population | 70%* | 27%** | 39%* | 57%** | |
| | Medium (10.54-29.52%) Black Population | 52%* | 87%* | 61%* | 35%** | |
| Population Structure | Low (< 49.07%) Female Population | 30%* | | | | |
| Socioeconomic status | Medium (2.15-6.24%) Employment in Extractive Industries | 69%*% | 73%* | | | 82%** |
| Housing Structure | Medium (20.51-28.23%) Renters | | | | | 78%* |
| Access and functional needs | Low (< 0.39 %) Nursing Home Residents Per Capita | 42%** | | | | |
| | Medium (0.40-0.76%) Nursing Home Residents Per Capita | 57%* | | | | |
| | Low (< 18.13%) population without health insurance | | | | | 59%* |
| | Medium (18.14-21.93%) population without health insurance | 44%* | | | | 65%** |
| Variable Significance: .05*, .01**, .005***, .001**** | | | | | | |

More indicators were influential in decreasing the likelihood of PTD across the study area. Counties with low and moderate Black populations are significantly less likely to have PTD than counties with high black populations. As expected, counties with low percent females, female-headed households, female labor force participation had a decreased likelihood of high PTD rates in comparison to counties with high percentages of these populations. However, the influence was not standard across all years. Random positive (decreasing) influence on several years of PTD was found for counties with low and medium extractive industry employment, per capita income, renters, nursing home residents, and English language proficiency compared to counties with high percentages indicators. Access and functional needs indicators were more influential in the earlier years (2000 – 2005) than in later years, indicating the presence of possible PTD related interventions for these groups in later years.

## Discussion

Model-independent (predictor) data, gathered from UCF's Vulnerability Mapping and Analysis Platform characterizes county populations based on the UCF Social Vulnerability Index (SoVI®)- a suite of socioeconomic indicators identified in disaster case study literature as useful for understanding lack of capacity to prepare for, respond to, or rebound from shocks and stresses (Table 3) [29]. Individually, social vulnerability variables identify drivers of community's capacity to cope with outcomes from a broad range of environmental hazards and disasters [12]. Only few age and economic status variables correlated at lower levels (.5 - .7) ensuring appropriate statistical power and reliability of variables in estimating birth outcomes individually [30,31].

Many different individual social variables were influential in one or more models of LBW and PTD rates, points toward a dire need to more comprehensively understand the links between social vulnerability and adverse birth outcomes. The present study identifies a suite of socio-demographic indicators predicting LBW and PTD rates. It is essential to move away from standard and simplified use of socio-economic indicators, including poverty as the sole means to understand adverse birth outcomes [5,9]. Rather, the field should utilize a more comprehensive view of social vulnerability, which provides a more robust understanding of drivers of adverse birth outcomes [21]. Second, knowledge of these more nuanced relationships between adverse birth outcomes and social vulnerabilities can be easily transformed into practical and impactful interventions. Findings here indicate that decreasing the unemployment rate positively affects adverse birth outcomes. As such, programs and policies targeting unemployment may become more appealing because an intervention focused on this more socioeconomic issue could have a dual impact on PTD and LBW.

While some data is collected about the mother, the suite of detailed SoVI data (n~30) is not currently collected systematically and comprehensively. Therefore, this assessment is set up as a summary level assessment where generally linkages between underlying social characteristics at the county level are compared to summary information about LBW and PTD. As such, an Ecological Fallacy, in which summary level socio-demographic indicators effectively represent every observation, is not created. Identifying the root connections between social characteristics and outcomes will only be possible by examining individual level characteristics. Future investigations should attempt to match socio-demographic with outcomes on a case-by-case basis. Such detailed data would likely provide noteworthy analytic results. Collection of more highly refined socio-demographic data will prove useful in such future analysis.

## Conclusion

While the social construct is not adequate alone to describe all adverse birth outcomes, individual variables play an essential role in low birth weights and preterm delivery. Although these findings indicate that adverse birth outcomes are linked with a more extensive set of underlying social vulnerabilities, one must recognize that social vulnerability manifests itself dynamically based on the multi-faceted and specific characteristics of populations.

Future studies may consider adding access and other health indicators like BMI, smoking, overall maternal health at the county level to this set of social indicators to evaluate a more robust set of LBW and PTD predictors. The interactions between influential variables and how they mediate pregnancy outcomes need to be investigated in future studies.

## Ethics Approval and Consent to Participate

Not Applicable

## Consent for Publication

Not applicable

## Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Competing Interests

The authors declare that they have no competing interests

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## Authors' Contribution

HF conceptualized the problem, developed the background and rationale, completed the statistical analysis, and was a major contributor in writing the manuscript. CE provided all social vulnerability data, set the analytic procedures, mentored HF in research, developed results, discussion, and conclusion section of the manuscript.

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Not Applicable

## Availability of Data and Materials

All datasets used during the current study are publicly available. The source of data is included for Social Vulnerability data (low birth weight and preterm birth) both the national average of and the county-level data.

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