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Identifying areas at risk of low birth weight using spatial epidemiology: A small area surveillance study

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ABSTRACT

Objectives. To assess the geographic distribution of Low Birth Weight (LBW) in New York State among singleton births using a spatial regression approach in order to identify priority areas for public health actions.

Methods. LBW was defined as birth weight less than 2500 g. Geocoded data from 562,586 birth certificates in New York State (years 2008–2012) were merged with 2010 census data at the tract level. To provide stable estimates and maintain confidentiality, data were aggregated to yield 1268 areas of analysis. LBW prevalence among singleton births was related with area-level behavioral, socioeconomic and demographic characteristics using a Poisson mixed effects spatial error regression model.

Results. Observed low birth weight showed statistically significant auto-correlation in our study area (Moran's I 0.16 p value 0.0005). After over-dispersion correction and accounting for fixed effects for selected social determinants, spatial autocorrelation was fully accounted for (Moran's I − 0.007 p value 0.241). The proportion of LBW was higher in areas with larger Hispanic or Black populations and high smoking prevalence. Smoothed maps with predicted prevalence were developed to identify areas at high risk of LBW. Spatial patterns of residual variation were analyzed to identify unique risk factors.

Conclusion. Neighborhood racial composition contributes to disparities in LBW prevalence beyond differences in behavioral and socioeconomic factors. Small-area analyses of LBW can identify areas for targeted interventions and display unique local patterns that should be accounted for in prevention strategies.

1. Introduction

Low birth weight (LBW) infants are at higher risk of increased mortality (Mathews, 2013), morbidity and disability in infancy and childhood that may lead to adverse health outcomes in adult life (Class et al., 2014; Zwicker and Harris, 2008; Goldenberg and Culhane, 2007). A high prevalence of LBW is highly correlated with prevalence of preterm birth and together they translate into higher health care costs which may result in a significant burden on society (Russell et al., 2007). Although LBW does not predestine a child to future ill-health, it remains one of the most widely available and accurate measure of birth outcomes (Wilcox, 2001). LBW is therefore considered an important indicator of public health status of a community.

New York State has one of the highest public health spending per person in the US, however, it ranks twenty first among all the US states in LBW prevalence (United Health Foundation and American Public Health Association, 2014). The latest birth certificate data suggests that though the LBW prevalence in New York State is close to the national average, racial disparities in LBW persist with non-Hispanic Black women having the highest LBW prevalence (New York State Department of Health, 2012; Martin et al., 2015). Racial disparity in LBW prevalence is considered an inequity because these differences are related to stresses and social conditions that more frequently affect the disenfranchised (Johnelle, 2009; Howell et al., 2008; Nkansah-Amankra et al., 2010). Reducing disparities in LBW is a healthcare priority in New York State (New York State Department of Health, 2012).

An individual's health is influenced by their physical and social environment, behaviors and genetic composition. Linking social and health data to a particular place is important because where we live influences our health (National Research Council and Institute of Medicine, 2013). Additionally, women belonging to racial minorities may be more susceptible to neighborhood effects than white women (Love et al., 2010). Therefore, public health and health promotion policies for addressing health disparities need to target both individual and area level factors. Geographic disparities in LBW have been documented in New York State (New York State Department of Health, 2012) and in other areas (Pattenden et al., 2011; Tu et al., 2012). Analyzing geographic disparities in health outcomes may help policy makers identify priority areas of action (Tu et al., 2012; Stopka et al., 2014). Many

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studies have assessed an overall effect of neighborhood socioeconomic status and LBW (Metcalfe et al., 2011). LBW data has been strongly related to social determinants which have distinct geographical patterns and therefore are likely to be correlated with one another over geographic space. It is important to determine whether the geographical differences in LBW distribution are largely due to the overall relationship between area socioeconomic deprivation and adverse pregnancy outcomes, or whether there are other geographically varying factors influencing outcomes.

Most previous studies that assessed multiple levels of influence on birth outcomes did not quantify the geographic variation in these associations nor formally test the component of variation contributed by socioeconomic disparities (Metcalfe et al., 2011). One UK study that explicitly described and quantified the variation that existed beyond random fluctuation, suggested that spatial autocorrelation remained unaccounted for after adjustments for individual behavioral and socioeconomic factors (Pattenden et al., 2011).

Spatial epidemiologic techniques may be useful in exploring and defining exposure-outcome relationships which may not be discovered using traditional epidemiologic techniques. Spatial epidemiology has traditionally been used for cluster detection for infectious diseases and environmental exposures but these methods have recently been employed in such areas as obesity research and assessing need for prenatal care services (Stopka et al., 2014). The present study aimed to use spatial regression analyses to assess the geographic distribution of LBW in New York State among singleton births and to quantify the extent to which geographic disparities are explained by individual and area-level determinants of poor birth outcomes. Specifically, we sought to map the disparities in LBW across New York State and, secondly, to assess the extent to which racial disparities in LBW are explained by behavioral risk factors such as smoking and access to care in different geographic areas. Finally we sought to identify areas at high risk of LBW infants to facilitate program interventions at a fine geographic scale.

2. Methods

The study population consisted of all singleton births in New York State (excluding New York City) for the years 2008–2012. We excluded births with missing birth-weight, or values <750 g, as lower values are unlikely to be live births, or addresses which could not be geocoded. LBW was defined as birth weight less than 2500 g. Teenage pregnancy was defined as age of mother less than 18 years at time of birth. Adequate Prenatal Care was defined using the Kessner Index which is based on the gestational age, month prenatal care began and number of prenatal care visits (Kessner et al., 1973). Smoking during pregnancy (Yes/No) and illicit drug use (Yes/No) is reported on the birth certificate. Total years of mother's education as reported on the birth certificate were used to calculate proportion of women with less than high school education. Mother's race and ethnicity is self-reported on the birth certificate. We categorized racial/ethnic groups as Hispanic, non-Hispanic white, non-Hispanic Black, and other. We used WIC participation (Yes/No) as a measure of socio-economic status for the mother. The WIC program is offered to all pregnant women in New York State who are on Federal assistance programs or whose family's annual household income is ≤185% Federal Poverty Level. We also evaluated area level variables derived from the 2008–2012 ACS survey and the SF1 from the 2010 census that included percent population under poverty, median per capita income, percent adults aged >25 years with less than high school education, percent NH whites, percent NH Blacks, and percent Hispanics and home ownership. Percentage of home ownership was calculated from 5 year estimates from the American Community Survey. This study was reviewed and approved by the New York State Department of Health Institutional Review Board and the Birth Registry.

Of the 2781 census tracts in the study area, births were reported in 2713 tracts. Birth data was geocoded by the New York State Vital Records registry in order to assign census tracts. To avoid unstable rates due to low number of births in some tracts the Geographic Aggregation Tool developed by the New York State Department of Health (currently available at http://www.albany.edu/faculty/ttalbot/GAT/) was used to aggregate census tract such that each unit had at least 250 births and the resulting areas were restricted to not cross county boundaries. This resulted in 1268 unique tract-areas in the study region. The only exception to aggregation within county boundaries was Hamilton County which was merged with two tracts from Warren County due to small number of total births. Using birth certificate data, we calculated prevalence of LBW, teenage mothers (age < 18 years), smokers, mothers with less than high school education, mothers who received adequate prenatal care and proportion of non-Hispanic white, non-Hispanic Black and Hispanic mothers in each tract-area.

2.1. Statistical analysis

A Moran's I test for spatial autocorrelation of low birth weight indicated that there was significant spatial autocorrelation. This suggested that the spatial configuration of the data should be accounted for in the analysis. The basic analytical spatial units for this study are aggregated census tracts (hereafter referred to as tract-areas), we used a geographic adjacency approach such that the neighborhood for a particular observation is the collection of other tract- areas with which it shares borders.

The pattern of LBW distribution indicated spatial contagion. The initial models assessed the individual determinants of LBW using variables from the birth certificate dataset. After determining that the best approach to account for spatial autocorrelation and yield the best model fit was a spatial error model using a Poisson distribution, we used a nested model approach to assess the relationship between predictors of LBW. Each reported model has two random error terms, the spatial error term u estimates the extent of variance that can be accounted by spatial dependency while the error term v is the residual variance (Appendix A). Model 1 included behavioral risk factors such as smoking, adequate prenatal care, illicit drug use and age of mother less than 18 years at pregnancy. Model 2 adds area level socioeconomic characteristics such as percent of WIC participants, percent with less than high school education and percent of housing which is owned by its resident. Model 3 provides estimates adjusted for area-level racial composition including percent of residents who were non-Hispanic Blacks and percent of residents identified as Hispanic. Finally model 4 adjusts for behavioral factors and area-level socioeconomic and racial composition.

The Moran's I statistic measures the degree of autocorrelation under the null hypothesis that there is no spatial autocorrelation in the data. The global Moran's I for residuals was therefore used to test for significant spatial autocorrelation for each model. While comparing models, the model with lower Akaike Information Criterion (AIC) was selected as having a better model fit (Kissling and Carl, 2008). All geo-statistical analysis was completed using SAS (Cary Institute, NC) and ArcGIS (Environmental Systems Research Institute, Redlands CA). To demonstrate the application of these results we chose to use Rochester city and its surrounding areas as an example. Rochester is New York State's third most populous city and the seat of the Monroe County. The city and surrounding areas show residential patterns similar to most cities in the US with a socially disadvantaged inner city urban area surrounded by higher socioeconomic status suburban areas.

3. Results

There were a total of 587,370 births in the New York study area. After excluding 23,559 plural births, 1074 singleton births with missing birth weight and 151 singletons with birthweight less than or equal to 750 g, there were a total of 562,586 singleton births in the study area for the 5 year study period. LBW prevalence in the area during the period 2008–2012 was 5.59% (Table 1). About 15.87% mothers reported