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Neighborhood and Individual-Level Risk Factors for Term Low Birth Weight: An Examination of Cross-Level Interactions in Los Angeles County, California

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Neighborhood and Individual-Level Risk Factors for Term Low Birth Weight: An Examination of Cross-Level Interactions in Los Angeles County, California

A thesis submitted in partial satisfaction

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Master of Science in Epidemiology

by

Elizabeth Agredano

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ABSTRACT OF THE THESIS

Neighborhood and Individual-Level Risk Factors for Term Low Birth Weight: An Examination of Cross-Level Interactions in Los Angeles County, California

by

Elizabeth Agredano

Master of Science in Epidemiology

University of California, Los Angeles, 2021

Professor Beate R. Ritz, Chair

This paper examines the association between term low birth weight (TLBW) and individual-level exposure to NO_2 and whether this association differs by neighborhood-level physical and social factors. Data consisted of birth records (n=97,200), measures of neighborhood-level social disadvantage, racial and ethnic segregation, and greenness. Unconditional logistic regressions revealed that exposure to high NO_2 levels in the third trimester is compatible with a weak positive association with TLBW after adjusting for maternal age, birthplace, race/ethnicity, smoking; infant sex; parity; and prenatal care payment type (aOR= 1.02, 95%CI=0.95, 1.09). To examine the presence of interaction, the model was re-run for each neighborhood covariate to include a product term. Evidence of a negative interaction between NO_2 and greenness was found. The odds of TLBW when NO_2 is high and greenness is low was lower compared to when NO_2 is low and greenness is high, corresponding to a point estimate of 1.00 (95%CI: 0.74 1.34) when exposure to high NO_2 levels is stratified at low NDVI.

The thesis of Elizabeth Agredano is approved.

Julia Heck

Michael Jerrett

May C. Wang

Beate R. Ritz, Committee Chair

University of California, Los Angeles

2021

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1. INTRODUCTION

It is widely acknowledged that social and physical contexts act as determinants of health outcomes, which can be as far-ranging as obesity, mental health illnesses, and cardiovascular ailments [1–4]. Previous studies have shown that neighborhood-level exposures impact health outcomes and that the effects of the neighborhood environment persist even when controlling for individual-level factors [5–7]. Physical aspects of a neighborhood, such as greenness and air pollution levels, and social factors such as neighborhood social deprivation and racial segregation, have been shown to impact birth outcomes [8].

Neighborhood greenness is associated with positive growth-related birth outcomes such as higher birth weights, larger cranial circumference, decreased risks of small for gestational age, and decreased risk of preterm birth [9–11]. The mechanism behind this association has not been defined. However, it has been postulated to exist because of the beneficial social effects of greenness (e.g., social cohesion, mental health benefits), environmental feedbacks (e.g., reduction in heat island effect, air pollution removal), and encouragement of health-promoting behavioral modification (e.g., fostering physical activity) [12–16].

Exposure to various forms of ambient air pollution has been shown to result in unfavorable birth outcomes. Exposure to NO_2 throughout pregnancy is associated with a higher risk of pregnancy loss, while third trimester CO_2 exposure is associated with term low birth weight (TLBW), and third trimester exposure to particulate matter results in a higher risk of TLBW, preterm birth, and overall reduced birth weight [17–19].

Measures of social inequity are associated with adverse birth outcomes and serve as a risk factor beyond individual-level factors. Whereas individual-level racial discrimination is associated with increased risk of adverse birth outcomes through the mechanism of pathophysiological responses to chronic stress, neighborhood-level racial segregation has been shown to independently increase the risk of preterm birth and TLBW in Black mothers [20–23]. Neighborhood SES affects birth outcomes multidimensionally and is associated with a variety of unfavorable reproductive health outcomes, including macrosomia, large for gestational age, preterm birth, and TLBW [24, 25]. It is hypothesized that physical characteristics of a neighborhood that lend to adverse birth outcomes such as poor access to goods and services, including reproductive health services, healthy foods, and recreation, are clustered among socially disadvantaged neighborhoods [8]. In contrast, social aspects that lend to positive birth outcomes such as social support, reciprocity, and stability are clustered among advantaged neighborhoods [8]. These contexts promote mechanisms that result in adverse birth outcomes. For example, perceived neighborhood instability is associated with preterm birth through the mechanism of psychological distress [26].

Often studies find that the effects of neighborhood-level social deprivation vary by individual maternal factors, or vice versa (e.g., higher odds of preterm birth or minorities) or that individual-level factors known to either cause or prevent unfavorable birth outcomes vary differently by area-level deprivation (e.g., medical insurance only preventative in low SES areas, African American race still associated with unfavorable outcomes despite high SES neighborhood) [27]. Following these findings, it is important to understand how individual-level factors interact with neighborhood-level factors in their association with unfavorable birth outcomes.

Despite the already established association between NO_2 on TLBW and the breadth of studies on the effect of neighborhood-level factors on health outcomes, this paper adds to the literature by examining whether joint effects exist between NO_2 and a variety of social and physical neighborhood-level factors. Further, this paper aims to establish the magnitude of joint effects. The hypothesis is that the effect of NO_2 on unfavorable birth outcomes will be heterogeneous across strata of social deprivation, racial and ethnic segregation, and greenness and that there will be an interaction between NO_2 and those factors. The odds of TLBW will be higher for those exposed to higher levels of NO_2 when adjusting for individual-level factors and when exposed to higher levels of neighborhood social deprivation, higher levels of neighborhood racial and ethnic segregation, and lower levels of greenness.

2. MATERIALS AND METHODS

2.1. Study Population

The sample was drawn from all live births recorded within Los Angeles County on California Birth Records between January 1st, 2019 and December 31st, 2019 (n=107,028). Preterm births (<37 gestational weeks completed) and records with missing gestational week data were excluded from the analysis resulting in a sample of 97,200. ArcGIS was used to geocode each birth record by the residential street address of the parent giving birth. Records with a P.O. Box, Unknown, or Missing response to the residence field were excluded from geocoding (n=28,510). ArcGIS ArcMap 10.7 was used to assign block group and city values to records with a spatial location.

2. 2. Birth Outcome

TLBW is a binary outcome derived from the California Birth Record obstetric estimate of gestation at delivery (weeks) and birth weight (grams) data. Records with gestational weeks>=37 and birth weight of <2,500g were classified as TLBW compared to those of >=37 weeks gestational age with weights at or above 2,500g, classified as term normal birth weight (TNBW).

2.3. Exposure Assessment

2.3.1 Individual Level Exposures

Individual-level traffic-related air pollution (NO_2) exposures were estimated using the land-use regression (LUR) model created by Su et al., 2009 [28]. The LUR estimates the spatial variation of NO_2 concentrations across Los Angeles County based on various inputs, including traffic volume, land use, vegetation greenness, soil brightness, and truck slope gradient data collected at two-hundred-and-one sampling sites whose locations were selected by a location-allocation algorithm. [29]. Residential addresses were assigned to the nearest California Air Resources Board (CARB), and the ratio of CARB value to LUR estimate was calculated for each month to create pregnancy-month-specific NO2 values [29]. These values account for spatial patterning of NO_2 as well as temporal changes [30]. NO_2 estimates were created for each trimester (i.e., first trimester= first day of last menses to day 92; second trimester= day 93 to day 182, third trimester = day 183 to delivery date) and for the pregnancy period.

2.3.2. Neighborhood Level Exposures

Neighborhood social disadvantage was estimated through the Area Deprivation Index (ADI), a validated composite index of 17 social determinants of health indicators drawn from the U.S. Census Bureau American Community Survey (ACS) [31]. The indicators include factors such as education, poverty, employment, and housing quality [32]. ADI estimates were acquired at the block group level using the R "Sociome" package with Los Angeles County as the region of interest and 2019 ACS 5-year estimates as the data source [33]. Estimates were linked to birth records on block group.

Exposure to green space was estimated using data from the National Aeronautics and Space Administration (NASA) Terra Moderate Resolution Imaging Spectroradiometer (*MODIS*) Vegetation Indices (*MOD13Q1*), which consist of 16-day values for the normalized difference vegetation index (NDVI), a measure often utilized as an indicator of greenness in urban health studies and shown to be appropriate for open space, which is applicable in the mixed land use county of Los Angeles [34, 35]. Data with low cloud cover for the period of December 18th, 2018 to December 18th, 2019 was downloaded from the Earth Explorer website and analyzed in ArcGIS to determine the greenest period of the year (March 22nd, 2019; county mean NDVI range = -0.2 – 0.99). As buffer sizes between 250m and 500m have been shown to offer the best estimation of directly accessible greenspace, a 250m buffer was generated around the birth record location and used as the input shapefile for Zonal Statistics as Table in ArcGIS Pro 2.8.0 to assign mean NDVI values to each birth record [36].

Racial and ethnic segregation was estimated through dissimilarity indices (i.e., Black versus White, Hispanic versus Non-Hispanic, respectively) calculated at the city-level after Bell, 1954 [37]. Dissimilarity indices measure the distributional uniformity of two groups across component geographies within a more extensive geography [38]. The dissimilarity index was calculated for cities based on component census tract data from the 2019 ACS 5-year estimates and linked to the birth record on the city.

2.4 Statistical Analysis

Statistical analyses were performed in SAS 9.4. Unconditional logistic regression analyses were conducted to establish crude odds ratios (cORs), adjusted odds ratios (ORs), and confidence intervals (CIs) of associations between NO_2 exposure at various time points within pregnancy (i.e., first trimester, second trimester, third trimester, whole pregnancy) and TLBW. The association of NO_2 on the outcome was analyzed per interquartile range (IQR) in NO_2 (IQR trimester 1= 0. 00798 ppm, IQR trimester 2=0.00802 ppm, IQR trimester 3= 0.00841 ppm, IQR pregnancy= 0.00546 ppm). Two crude models were performed, the first including no covariates, and the second including only infant sex and previous trimester NO_2 where applicable. Fully adjusted models additionally controlled for variables established through previous studies to affect both the exposure and the outcome, including maternal age (<19, 20-25, 25-29, 30-34, >=35 years old), maternal race/ethnicity (White, non-Hispanic, Hispanic, any Race, Black, Asian/Pacific Islander, Two or More Races, Other), Parity (first birth, second birth, third birth or higher), maternal birthplace (the U.S. Born, non-U.S. born), maternal smoking (ever smoker, non-smoker) and payment type of prenatal care as a proxy for individual-level socioeconomic status (private, Medi-Cal/ Government/ self-pay, Other/ No-Prenatal) [39].

Crude and adjusted unconditional logistic regressions were used to examine the association between the outcome and each individual neighborhood-level factor (e.g., ADI, NDVI, Black dissimilarity, Hispanic dissimilarity), which included the neighborhood covariate and control for maternal age, birthplace, race/ethnicity, and smoking; infant sex; parity; and prenatal care payment type. ADI and NDVI were classified by quartile, whereas the racial and ethnic dissimilarity indices were classified by segregation level (>=0.30 as “low segregation”; 0.31–0.59 as “average segregation,” 0.6 –1.0 as “high segregation) after Massey and Dentey [40].

To examine the presence of interaction among NO_2 and the neighborhood-level factors, the adjusted unconditional logistic regressions analyses controlling for individual covariates were run separately to include NO_2 classified into quartiles, each neighborhood-level factor, and an interaction term between NO_2 and the neighborhood-level factor of interest. The joint tests were examined, and stratified analyses of the association between high NO_2 and LTBW were examined at each neighborhood strata.

3. RESULTS

Term births characterized by low birth weight were more likely to be female infants born to either younger (4.1% in TLBW compared to 3.4% in TNBW) or older (28.8% compared to 26.8%) mothers with a high school degree (24.7% compared to 23.4%), who did not smoke, and who either did not make use of prenatal care or paid for it with a source other than government, self-pay, or private insurance (See Table 1a.). Term births of low birth weight also tended to be born to mothers with lower NO_2 exposure, lower area social deprivation, higher NDVI, and average to high racial segregation (See Table 1a.)

At the block group level, social disadvantage in Los Angeles ranged from 50.8 to 168.1, with a median of 98.9 (see Table 1b). Hispanics are generally equally distributed within cities in Los Angeles County when compared to non-Hispanics, with a majority (88.4%) of cities characterized by low ethnic segregation, and the remaining cities characterized by medium ethnic segregation; no cities were characterized by high segregation (See Table 1b). About half of cities (53.5%) in Los Angeles County are characterized by low racial segregation, and over a third (37.3%) are characterized by medium racial segregation, with the remaining (6.3%) characterized by high segregation (See Table 1b). The range of NDVI in Los Angeles County is --0.2 to .99, and at the city-level, mean NDVI ranged from 0.7 to 0.65 with a median, mean NDVI of 0.32 (See Table 1b).

Unconditional logistic regressions between trimester and whole pregnancy NO_2 and TLBW revealed a weak protective factor in unadjusted models (trimester 1 OR=0.91, 95% CI=0.86, 0.96; trimester 2 OR=0.92, 95% CI=0.87, 0.98; trimester 3 OR=0.99, 95% CI=0.94, 1.05; and whole pregnancy OR= 0.88, 95% CI=0.88, 0.98). Models adjusted for only infant sex and previous trimester NO_2 resulted in similar point estimates and CIs as the fully adjusted model. Only third trimester NO_2 showed a potential positive association with TLBW in those exposed to high levels of NO_2 versus low (aOR=1.02, 95%CI=0.95, 1.09) (See Table 2a.).

Fully adjusted neighborhood-level models suggest that the data is compatible with a weak to a strong positive association between racial segregation and the outcome (aOR=1.37, 95%CI=1.02, 1.87) when racial segregation is high versus when it is low (see Table 2b.). The point estimate for ADI (aOR=1.03, 95%CI=0.89, 1.19) is centered around the null, and the CI includes the null. This suggests that although the data may be compatible with a weak to a moderately positive association between high ADI and LTBW, a protective association cannot be ruled out (See Table 2a.). Similarly, the point estimate for NDVI is below the null (aOR=0.94, 95%CI =0.87, 1.11), which is compatible with a negative association with LTBW when NDVI is low versus when it is high. Although, the CI range suggests that the data may be compatible with a positive association between low NDVI and LTBW. Ethnic segregation exhibits the smallest CI of all neighborhood-level factors and is compatible with a weak to a moderate positive association between high ethnic segregation and LTBW (aOR=1.07, 95%CI=0.98, 1.27) (See Table 2a.)

The ADI and racial and ethnic segregation tests for joint effects yielded large p-values for the interaction term, which if the models are correct and there are no other sources of bias, would suggest that the data is incompatible with heterogeneity across strata of these neighborhood-level factors and that there is insufficient evidence to claim interaction exists between high NO_2 exposure and high ADI (p=0.61), high racial segregation (p=.07) or high ethnic segregation (p=.61) on the outcome of LTBW (See Table 3a.). The test for joint effects between NO_2 and NDVI yielded a p-value of 0.02 for the interaction term, which suggests that the data is incompatible with homogeneity across strata of greenness and that there is sufficient evidence to claim an interaction between NO_2 and greenness. After adjusting for birth and maternal variables, the odds of LTBW among those exposed to high NO_2 and low NDVI was 0.77 times that of those exposed to low NO_2 and high NDVI. The measure of interaction on the additive scale is 0.8, whereas the measure on the multiplicative scale is 0.78 suggesting subadditivity and submultiplicativity (see Table 3b). Under stratified analysis, this corresponds to a point estimate of 1.00 (95%CI: 0.74, 1.34) for high NO_2 versus low NO_2 within strata of low NDVI. Although the stratified point estimate is inconclusive with a large CI and a null point estimate, it does not account for the interaction between NO_2 and NDVI and may still be compatible with a negative association between high NO_2 and TLBW when NDVI is low.

4. DISCUSSION

The association between individual-level NO_2 and TLBW was examined as a precursor to investigating the cross-level interactions between individual-level exposures and an inclusive set of neighborhood-level factors that act as risk and protective factors for the outcome. NO_2 in the third trimester was found to be compatible with a weak increase in odds of TLBW.

Tests for interaction were mostly not compatible with heterogeneity across neighborhood-level strata and suggested a lack of interaction between NO_2 and most neighborhood-level physical and social factors. A negative interaction between high NO_2 and low NDVI on TLBW was found. This result adds to the conversation concerning the effects of greenness in concert with air pollution. While some studies indicate a positive synergism between air pollution and greenness on birth outcomes such as preterm birth, others are inconclusive [40, 41]. The negative association between high NO_2 when NDVI is low calls into question the purported protective nature of high greenness. Anabitarte et al. (2019) found a negative direct effect of greenness on birth weight when NO_2 was treated as a mediator [42]. One potential explanation for the negative interaction of low NDVI and high NO_2 on TLBW is the relationship between urban vegetation, ozone (O3), and NO2, whereby urban vegetation emits biogenetic volatile organic compounds (BVOC) which readily react with NO_x to form ozone, which in turn reacts with NO to form temporary excess NO_2 concentration [43–45]. The lack of vegetation may be protective due to a limited input of BVOC. A second possible explanation is that the patterning of low NDVI corresponds with access to services that promote normal birth weight. The spatial distribution of Los Angeles hospitals and medical centers coincides with low NDVI areas (see Figure. 1). However, more investigation is warranted to understand the mechanism behind the negative interaction between lack of greenness and high air pollution on TLBW.

4.2 Limitations and Recommendations

The results of this examination may be strengthened through an increase in sample size and more robust neighborhood-level measures. Although a power calculation (power=0.8, sample TLBW prevalence=2.25%, national TLBW prevalence=8.1%) suggests a sample of just over 250 is sufficient to estimate effect size, it may be beneficial to increase the sample size to run interaction analyses [46]. In addition, when examining descriptive statistics, infants in the sample born at TLBW have a higher probability of factors generally associated with TNBW, such as being born to a non-smoking mother or being first born. This may be due to more missing values in the outcome category for these fields than in the comparison group, which may be remedied through supplementation with additional birth records.

Another limitation of this analysis is the lack of complete raster data for coastal areas in Los Angeles County. Although there were equal percentages (3.1%) of missing NDVI data for the outcome group and the comparison group, it would be beneficial to analyze the interaction between NDVI and NO_2 using a complete raster dataset. Future analysis could review other sources for vegetation index assignment, such as surface reflectance data sourced from Landsat. Lastly, this analysis would benefit from a multi-level model approach to establish whether clustering exists within neighborhoods and to account for clustering if it is present to arrive at a more robust estimate of association.

4.3 Conclusion

This examination found that third-trimester exposure to air pollution and racial segregation have a positive association with TLBW when controlling for covariates and that there exists a negative interaction between low amounts of greenness and high air pollution on TLBW. Analysis of interactions between exposures allows public health professionals to focus intervention efforts. When funding is limited, it is crucial to focus intervention efforts on exposures or combinations of exposures that provide the most benefit. When interaction effects surprise us, such as the negative interaction between high air pollution and low vegetation, it calls upon public health professionals to think creatively. Whereas a neighborhood-level intervention of tree planting may not result in positive birth outcomes, targeting air pollution at the source may. At the same time, the results from this analysis reiterate the importance of addressing racism and how historical racist practices lend to health inequity in the present in order to advance reproductive health for all.

TABLES

Table 1a. Demographic and pregnancy characteristics of the study population in Los Angeles County. California Birth Records, 2019.

Characteristic	Term Low Birth weight		Term Normal Birth weight	
	N=2,414	**%**	**N=94,786**	**%**
Infant Sex				
Female	1375	57.0	45,943	48.5
Male	1039	43.0	48,842	51.5
Missing	0	0.0	1	0.0
Maternal Age				
<19	100	4.1	3,239	3.4
20-24	338	14.0	13,490	14.2
25-29	569	23.6	23,283	24.6
30-34	712	29.5	29,351	31.0
>=35	695	28.8	25,412	26.8
Missing	0	0.0	11	0.0
Maternal Education				
Less than High School	311	12.9	12,566	13.3
High school graduate	597	24.7	22,215	23.4
Some College or Associate's Degree	563	23.3	24,182	25.5
College Graduate or Higher	856	35.5	33,477	35.3
Missing	87	3.6	2,346	2.5
Maternal Race/Ethnicity				
White, non-Hispanic	401	16.6	19,610	20.7
Hispanic, any Race	1147	47.5	50,820	53.6
Black	268	11.1	6,340	6.7
Asian/Pacific Islander	485	20.1	14,745	15.6
Two or More Races	50	2.1	1,541	1.6
Other	8	0.3	247	0.3
Missing	55	2.3	1,483	1.6
Parity				
1st Birth	1177	48.8	39,097	41.3
2nd Birth	671	27.8	30,800	32.5
3 or more	561	23.2	24,839	26.2
Missing	5	0.2	50	0.1
Prenatal Care				
Yes	2377	98.5	93,920	99.1
No	28	1.2	660	0.7
Missing	9	0.4	206	0.2
Payment type of prenatal care				
Private	1109	45.9	44,830	47.3
MediCal/Govt/ self-pay	1201	49.8	47,152	49.8
Other/ No-Prenatal	95	3.9	2,598	2.7
Missing	9	0.4	206	0.2

Table 1a. (Continued) Demographic and pregnancy characteristics of the study population in Los Angeles County. California Birth Records, 2019.

Maternal Birthplace				
US	1529	63.3	58,028	671.2
Non-US countries	876	36.3	36,415	38.4
Missing	9	0.4	343	0.4
Maternal Smoking				
Yes	2365	98.0	93,607	98.8
No	28	1.2	598	0.6
Missing	21	0.9	581	0.6
Third Trimester NO_2 Quartile				
1 (Lowest)	589	24.4	22,927	24.2
2	583	24.2	23,058	23.7
3	588	24.4	23,140	24.4
4 (Highest)	576	23.9	22,862	24.1
Missing	78	3.2	2,799	3.0
Area Deprivation Index Quartile				
1 (Lowest)	586	24.3	23,178	24.5
2	588	24.4	23,170	24.4
3	593	24.6	23,160	24.4
4 (Highest)	588	24.4	23,161	24.4
Missing	59	2.4	2,117	2.2
NDVI Quartile				
1 (Lowest)	596	24.7	23,095	24.4
2	594	24.6	23,093	24.4
3	576	23.9	23,102	24.4
4 (Highest)	584	24.2	23,111	24.4
Missing	64	2.7	2,385	2.5
Dissimilarity Index, Black				
Low Segregation (<=0.3)	698	28.9	28336.0	29.9
Average Segregation	1598	66.2	62,502	65.9
High Segregation (>=0.6)	57	2.4	1,777	1.9
Missing	61	2.5	2,171	2.3
Dissimilarity Index, Hispanic				
Low Segregation (<=0.3)	1092	45.2	43946	46.36
Average Segregation	1261	52.2	48,669	51.4
High Segregation (>=0.6)	0	0.0	0	0.0
Missing	61	2.5	2,171	2.3

Table 1b. Descriptive statistics of Los Angeles County neighborhood-level factors, 2019.

Measure	N=142	%
Dissimilarity Index, Black*		
Low Segregation (<=0.3)	76	53.5
Average Segregation	53	37.3
High Segregation (>=0.6)	9	6.3
Missing	4	2.8
Dissimilarity Index, Hispanic*		
Low Segregation (<=0.3)	122	85.9
Average Segregation	16	11.3
High Segregation (>=0.6)	0	0.0
Missing	4	2.8
Measure	**N=638,600**	
ADI†		
Min	50.8	
Median	98.9	
Max	168.1	
IQR	30.2	
Measure	**N=142**	
NDVI‡		
Min	0.07	
Median	0.32	
Max	0.65	
IQR	0.19	

*Measured at the city-level. Source: ACS 5-Year Estimates
†Measured at the block-group level. Source: Sociome
‡Presented at the city-level. Source: NASA

Table 2a. NO_2 trimester and whole pregnancy associations with term low birth weight

Characteristic	Crude Odds Ratio (cOR)*		Crude Odds Ratio (cOR)†		Adjusted Odds Ratio (aOR)‡	
	cOR	**95% CL**	**aOR**	**95% CL**	**aOR**	**95% CL**
NO_2						
1st Trimester	0.91	0.86, 0.96	0.91	0.86, 0.96	0.9	0.85, 0.95
2nd Trimester	0.92	0.87, 0.98	0.96	0.90, 1.03	0.94	0.88, 1.01
3rd Trimester	0.99	0.94, 1.05	1.03	0.96, 1.10	1.02	0.95, 1.09
Whole Pregnancy	0.93	0.88, 0.98	0.93	0.89, 0.98	0.91	0.86, 0.96

*Modeling the odds of TLBW for every IQR increase in NO_2

†Modeling the odds of TLBW for every IQR increase in NO_2, controlling for infant sex and previous trimester NO_2

‡Adjusted for infant sex, maternal age, maternal race/ethnicity, maternal birthplace, maternal smoking, payment type, and parity

Table 2b. Neighborhood-level associations with term low birth weight

Characteristic	Crude Odds Ratio (cOR)		Crude Odds Ratio (cOR)¶	
	cOR	**95% CL**	**aOR**	**95% CL**
ADI*	1.00	0.89, 1.13	1.03	0.89, 1.19
NDVI†	0.98	0.87, 1.10	0.94	0.87, 1.11
Dissimilarity, Black§	1.30	0.99, 1.71	1.37	1.02, 1.87
Dissimilarity, Hispanic‡	1.04	0.96, 1.13	1.07	0.98, 1.17

*Modeling the odds of TLBW for Quartile 4 (highest) versus Quartile 1 (lowest)
†Modeling the odds of TLBW for Quartile 4 (highest) versus Quartile 1 (lowest)
‡Modeling the odds of TLBW for high segregation versus low segregation
§Modeling the odds of TLBW for average segregation versus low segregation
¶Adjusted for infant, maternal age, maternal race/ethnicity, maternal birthplace, maternal smoking, payment type, and parity

Table 3a. Joint test results for neighborhood-level model product terms

Interaction Term	DF	Wald Chi-Square	Pr>Chisq
NO_2 *ADI	9	7.26	0.61
NO_2 *NDVI	9	19.71	0.02
NO_2 *Dissimilarity, Black	6	7.58	0.27
NO_2 *Dissimilarity, Hispanic	3	1.79	0.62

Table 3b. Fully adjusted joint effect model between term low birth weight and high NO_2, low NDVI, or both

	NDVI			
	High NDVI		Low NDVI	
NO_2	TLBW/ TNBW* N	aOR	TLBW/ TNBW* N	aOR
Low NO_2	65 / 3,021	1.00	231 / 8,291	0.74
High NO_2	188/8,157	1.06	94 /3,395	0.77

*Frequency of term low birth weight and term normal birth weight
†Measure of interaction on additive scale: RERI = 0.77= 1.06+0.74 -1 | 0.77<0.8 (subadditive)
‡Measure of interaction on multiplicative scale: ratio of ORs = 0.77 = .74*1.06 | 0.77<0.78 (submultiplicative)
§ORs are adjusted for infant sex, maternal age, maternal race/ethnicity, maternal birthplace, maternal smoking, payment type, and parity

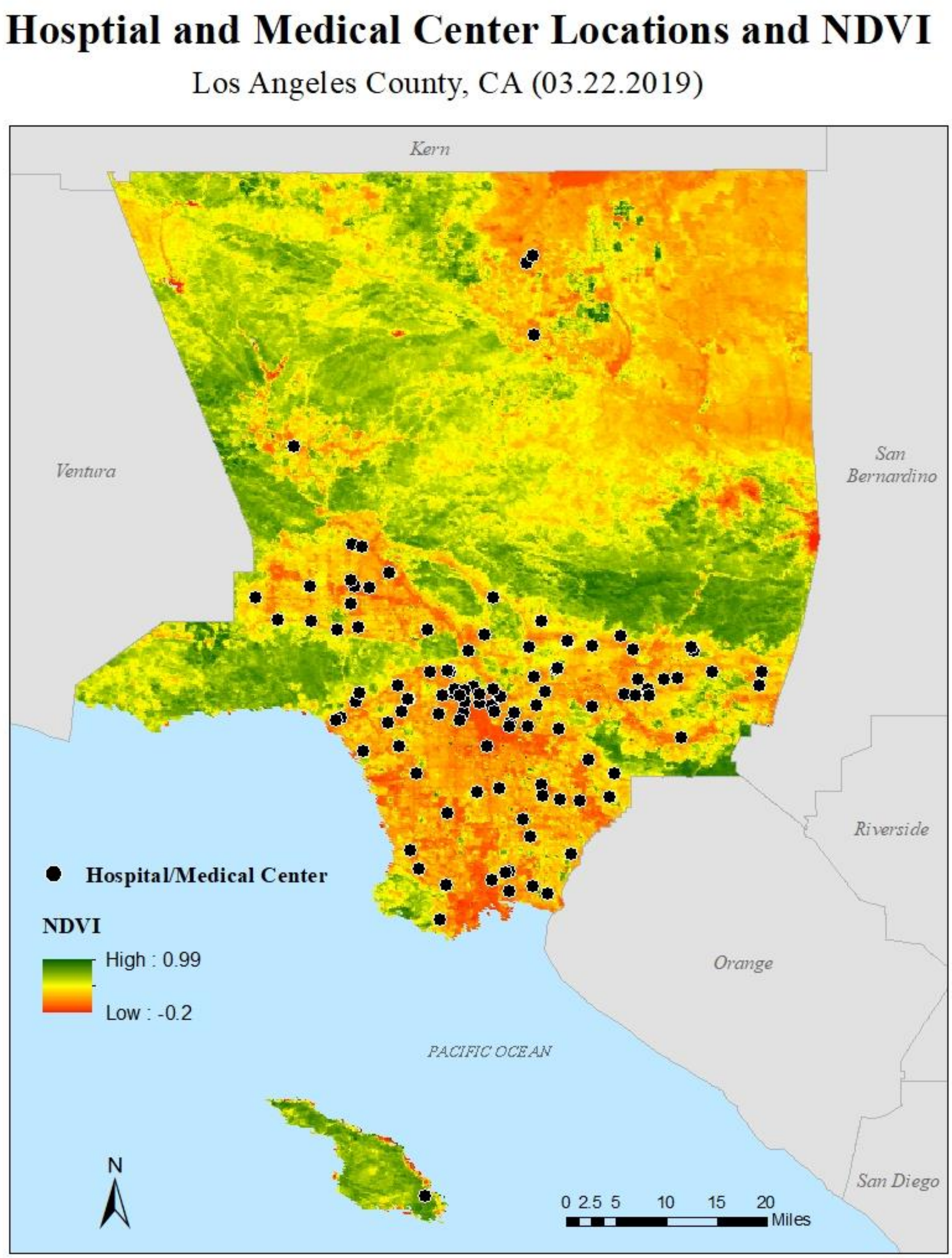
Table 3c. Third trimester NO_2 associations with term low birth weight, stratified by NDVI Quartile*

Characteristic	Adjusted Odds Ratio (aOR)‡	
	aOR	**95% CL**
NDVI		
Q1	1.00	0.74, 1.34
Q2	1.25	0.98, 1.6
Q3	1.04	0.96, 1.12
Q4	0.93	0.72, 1.19

*Modeling the odds of term low birth weight for when NO2 is high versus when it is low
†Adjusted for infant sex, maternal age, maternal race/ethnicity, maternal birthplace, maternal smoking, payment type, and parity

FIGURES

Figure 1. Map showing LA County hospital/ medical center locations and NDVI



NDVI Data Source: NASA

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