# Environmental Justice Index and adverse pregnancy outcomes

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**BACKGROUND:** The Environmental Justice Index is a tool released by the Centers for Disease Control and Prevention that quantifies and ranks the environmental burden and social vulnerability of each census tract. Racial and ethnic disparities in adverse pregnancy outcomes are well established. The relative contributions of individual (person-level) and environmental (neighborhood-level) risk factors to disease prevalence remain poorly understood.

**OBJECTIVE:** This study aimed to determine whether the Environmental Justice Index is associated with adverse pregnancy outcomes after adjustment for individual clinical and sociodemographic risk factors.

**STUDY DESIGN:** This was a retrospective cross-sectional study of all patients who delivered a singleton newborn at ≥23 weeks of gestation between January 2019 and February 2022 at 7 hospitals within a large academic health system in New York. Patients were excluded if their home address was not available, if the address could not be geocoded to a census tract, or if the census tract did not have corresponding Environmental Justice Index data. Patients were also excluded if they had preexisting diabetes or hypertension. For patients who had multiple pregnancies during the study period, only the first pregnancy was included for analysis. Clinical and demographic data were obtained from the electronic medical record. Environmental Justice Index score, the primary independent variable, ranges from 0 to 1. Higher Environmental Justice Index scores indicate communities with increased cumulative environmental burden and increased social vulnerability. The primary outcome was adverse pregnancy outcome, defined as the presence of ≥1 of any of the following conditions: hypertensive disorders of pregnancy, gestational diabetes, preterm birth, fetal growth restriction, low birthweight, small for gestational age newborn, placental abruption, and stillbirth. Multivariable logistic regression was performed to investigate the relationship between Environmental Justice Index score and adverse pregnancy outcome, adjusting for potential confounding variables, including body mass index group, race and ethnicity group, advanced maternal age, nulliparity, public health insurance, and English as the preferred language.

**RESULTS:** A total of 65,273 pregnancies were included for analysis. Overall, adverse pregnancy outcomes occurred in 37.6% of pregnancies (n=24,545); hypertensive disorders of pregnancy (13.4%) and gestational diabetes (12.2%) were the most common adverse pregnancy outcome conditions. On unadjusted analysis, the strongest associations between Environmental Justice Index score and individual adverse pregnancy outcome conditions were observed for stillbirth (odds ratio, 1.079; 95% confidence interval, 1.025−1.135) and hypertensive disorders of pregnancy (odds ratio, 1.052; 95% confidence interval, 1.042−1.061). On multivariable logistic regression, every 0.1 increase in Environmental Justice Index score was associated with 1.4% higher odds of adverse pregnancy outcome (adjusted odds ratio, 1.014; 95% confidence interval, 1.007−1.021). The strongest associations with adverse pregnancy outcomes were observed with well-established clinical and social risk factors, including class 3 obesity (adjusted odds ratio, 1.710; 95% confidence interval, 1.580−1.849; reference: body mass index <25 kg/m$^2$) and certain race and ethnicity groups (reference: non-Hispanic White), particularly Asian and Pacific Islander (adjusted odds ratio, 1.817; 95% confidence interval, 1.729−1.910), and non-Hispanic Black (adjusted odds ratio, 1.668; 95% confidence interval, 1.581−1.760) people.

**CONCLUSION:** Environmental Justice Index score is positively associated with adverse pregnancy outcomes, and most strongly associated with stillbirth and hypertensive disorders of pregnancy. Geospatial analysis with Environmental Justice Index may help to improve our understanding of health inequities by identifying neighborhood characteristics that increase the risk of pregnancy complications.

**Key words:** census tract, deprivation, development, diabetes, environment, fetal, growth, hypertension, maternal, neighborhood, pollution, preeclampsia, social, stillbirth, toxins, vulnerability

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## AJOG Global Reports at a Glance

### Why was this study conducted?

This study was conducted to determine the association between the Environmental Justice Index (EJI), which quantifies the social vulnerability and environmental burden of each census tract, and adverse pregnancy outcomes (APOs).

### Key findings

In a large, diverse population of patients, EJI was independently but weakly associated with APOs after adjusting for covariate factors. Of the adverse maternal and fetal outcomes included in the composite definition of APO, EJI was most strongly associated with stillbirth and hypertensive disorders of pregnancy. Although both individual and neighborhood characteristics were associated with APOs, the strongest associations were observed with class 3 obesity and certain race and ethnicity groups, particularly Asian and Pacific Islander, and non-Hispanic Black.

### What does this add to what is known?

Geospatial analysis with EJI may help to improve our understanding of health inequities by identifying neighborhood characteristics that increase the risk of pregnancy complications.

## Introduction

Several physiological changes occur during pregnancy to support the development of the fetus and prepare for the demands of childbirth and breastfeeding. These vascular, metabolic, and physiological adaptations produce stress, which may unmask underlying susceptibility to future disease.[1,2] Adverse pregnancy outcomes (APOs) are maternal or fetal complications that not only affect pregnancy but also increase the likelihood that a pregnant patient will develop cardiovascular disease (CVD) risk factors and actual cardiometabolic disorders. A recent scientific statement from the American Heart Association includes the following conditions in the definition of APO: hypertensive disorders of pregnancy (HDP), gestational diabetes mellitus (GDM), preterm birth (PTB), fetal growth restriction (FGR), low birthweight (LBW), small for gestational age neonates (SGA), placental abruption, and stillbirth.[3] These complications occur more often in pregnant patients who have preexisting cardiometabolic risk factors or a genetic or environmental predisposition.[3]

Racial and ethnic disparities in APOs are well-described.[4–6] The relative contributions of individual (person-level) and environmental (neighborhood-level) risk factors to disease prevalence remain poorly understood.[7,8] Geospatial analysis may help to improve our understanding of health inequities by identifying neighborhood characteristics that increase risk of disease.[9,10] The Environmental Justice Index (EJI) is a tool released by the Centers for Disease Control and Prevention (CDC) that quantifies and ranks the environmental burden and social vulnerability of each census tract in the United States.[11] Environmental justice is the idea that all people and communities should have the same degree of protection from environmental and health hazards, and equal involvement in decision-making processes that affect the health of their environment.[12] Socially marginalized groups are at increased risk for a variety of environmental exposures; this disproportionate burden is often referred to as environmental racism.[13] The EJI score is based on the following 3 components or modules: social vulnerability, environmental burden, and health vulnerability. Environmental burden includes various forms of pollution, the presence of potentially hazardous or toxic sites, and any features thought to be detrimental (pathogenic) to human health. Salutogenic features, those that contribute to good health, are also incorporated into the EJI score, including walkability and the presence of recreational parks. Social vulnerability includes racial/ethnic minority status, socioeconomic status, household characteristics, and housing type. Although there is no previous literature on environmental burden and pregnancy outcomes, studies have evaluated the relationship between neighborhood social vulnerability and outcomes such as PTB, SGA, LBW, stillbirth, and severe maternal morbidity (SMM).[14–16]

The objective of this study was to determine whether EJI is associated with APOs after adjustment for other individual clinical and sociodemographic risk factors. We hypothesized that higher EJI scores, which signify neighborhoods with increased social vulnerability and environmental burden, would be associated with increased risk of APOs but have a smaller effect than individual risk factors.

## Materials and Methods

This was a retrospective cross-sectional study of all patients who delivered a singleton newborn at ≥23 weeks of gestation between January 2019 and February 2022 at 7 hospitals within a large academic health system in New York. Patients were excluded if their home address was not available, if the address could not be geocoded to a census tract, or if the census tract did not have corresponding EJI data. Patients with preexisting diabetes or hypertension were also excluded because they were not at risk for certain APOs according to their underlying conditions. For patients who had multiple pregnancies during the study period, only the first pregnancy was included for analysis. This research adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist for observational studies (https://www.strobe-statement.org). The Northwell Health Institutional Review Board approved this study as minimal-risk research using data collected for routine clinical practice, and waived the requirement for informed consent.

Patient clinical characteristics, sociodemographic data, and home addresses were obtained from the inpatient electronic medical record system (Sunrise

Clinical Manager, Allscripts Healthcare Solutions, Inc., Chicago, IL). Maternal comorbidities and pregnancy complications were identified from structured clinical documentation during the delivery hospitalization and from ICD-10-CM (International Classification of Diseases, Tenth Revision, Clinical Modification) codes. Baseline demographic data included maternal age, parity, race, ethnicity, body mass index (BMI) at delivery, type of health insurance, and preferred language. Self-identified race and ethnicity were selected from prespecified categories at the time of hospital admission. For the purposes of our analysis, the individual variables of race and ethnicity were combined into 1 variable and referred to as the race and ethnicity group. Patient home addresses were used to identify census tracts, which were then linked to EJI scores released by the CDC.

The primary exposure was EJI score, a percentile ranking that ranges from 0 to 1. Higher EJI scores indicate communities with increased cumulative environmental burden and increased social vulnerability. EJI is calculated using data from the US Census Bureau, the US Environmental Protection Agency, the US Mine Safety and Health Administration, and the CDC.[11] The 2022 EJI data release was used for this study. The overall EJI score is based on the following 3 components or modules: social vulnerability, environmental burden, and health vulnerability. For the purposes of our study, the social-environmental ranking (RPL_SER) was used, which excludes the health vulnerability module. For simplicity, RPL_SER is referred to as EJI score in this article. The authors of the EJI Technical Documentation discourage the use of the overall EJI score (RPL_EJI) for studies evaluating relationships between environmental factors and health outcomes because health vulnerability factors (eg, hypertension, diabetes, asthma) are already included within that ranking.

The primary outcome was APO, a binary variable. APO was defined as the presence of ≥1 of any of the following conditions: HDP, GDM, PTB, FGR, LBW, SGA, placental abruption, and stillbirth.[3]

Descriptive statistics were used to characterize the data. Continuous variables are presented as means and standard deviations. Categorical variables are expressed as number and percentage. For continuous variables, comparisons between groups were performed using the Student *t*-test. The chi-square test was used to examine associations between categorical variables. Unadjusted logistic regression and the Wilcoxon rank-sum test were used to evaluate the association between EJI and each individual APO outcome. Multivariable logistic regression was performed to investigate the relationship between EJI score and (composite) APO, adjusting for potential confounding variables that are known to be associated with APOs, including BMI group, race and ethnicity group, advanced maternal age (AMA), nulliparity, public health insurance, and English as the preferred language.[3,4] AMA was defined as ≥35 years at the time of delivery. A second regression model evaluated the association between the social vulnerability module of EJI and APO, excluding the environmental burden module. Forest plots were produced to visually depict adjusted odds ratios (aORs) with their corresponding 95% confidence intervals (CIs). *P* value <.05 was used to define statistical significance. The sample size was determined on the basis of data availability rather than formal statistical power calculations. SAS 3.8 Enterprise Edition (SAS Institute Inc., Cary, NC) was used to conduct analyses.

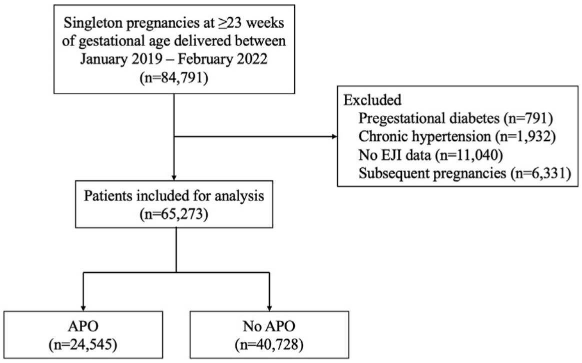
## Results

A total of 65,273 pregnancies were included for analysis after exclusion criteria were applied (Figure 1). Non-Hispanic White patients constituted the largest race and ethnicity group (43.6%), followed by patients who identified as Hispanic (18.0%), Asian or Pacific Islander (13.6%), and non-Hispanic Black (12.0%). Baseline characteristics are presented in Table 1. Most patients had private health insurance (67.4%), spoke English as their preferred language (92.2%), and were aged <35 years at delivery (70.3%).

Overall, APOs occurred in 37.6% of pregnancies (n=24,545); HDP (13.4%) and GDM (12.2%) were the most common APOs observed (Table 2). Figure 2 shows the prevalence of each EJI decile within the cohort and the corresponding APO rates. The APO rate increased from 31.0% among patients with an EJI score <0.1 (first decile) to >40% when EJI scores were ≥0.8 (top 2 deciles).

On unadjusted analysis (Table 2), for every 0.1 increase in EJI score, there was a 3.6% increase in the odds of APO (odds ratio [OR], 1.036; 95% CI, 1.029 −1.042). The strongest associations between EJI score and individual APO conditions were observed for stillbirth

**FIGURE 1**
**Patient flowchart**




*APO*, adverse pregnancy outcome; *EJI*, Environmental Justice Index.

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**TABLE 1**
**Baseline characteristics of the study population**

| Characteristic | No APO (n=40,728) | APO (n=24,545) | *P* value |
|---|---|---|---|
| Maternal age, y | | | |
| ≥35 | 11,368 (27.9) | 8031 (32.7) | <.001 |
| BMI at delivery, kg/m$^2$ | 30.6±5.5 | 31.6±6.4 | <.001 |
| <18.5 | 31 (0.1) | 34 (0.1) | <.001 |
| 18.5−24.9 | 4342 (10.7) | 2685 (10.9) | |
| 25.0−29.9 | 14,392 (35.3) | 7416 (30.2) | |
| 30.0−34.9 | 11,033 (27.1) | 6415 (26.1) | |
| 35.0−39.9 | 4598 (11.3) | 3339 (13.6) | |
| ≥40.0 | 2103 (5.2) | 2253 (9.2) | |
| Unknown or declined | 4229 (10.4) | 2403 (9.8) | |
| Race and ethnicity | | | |
| Non-Hispanic White | 19,406 (47.6) | 9073 (37.0) | <.001 |
| Non-Hispanic Black | 4212 (10.3) | 3617 (14.7) | |
| Hispanic | 7406 (18.2) | 4362 (17.8) | |
| Asian or Pacific Islander | 4785 (11.7) | 4061 (16.5) | |
| American Indian or Alaska Native | 188 (0.5) | 199 (0.8) | |
| Other or multiracial | 3388 (8.3) | 2335 (9.5) | |
| Unknown or declined | 1343 (3.3) | 898 (3.7) | |
| Nulliparity | 17,542 (43.1) | 12,585 (51.3) | <.001 |
| Preferred language English | 37,564 (92.2) | 22,636 (92.2) | .97 |
| Public health insurance | 12,957 (31.8) | 8317 (33.9) | <.001 |

*APO*, adverse pregnancy outcome; *BMI*, body mass index.

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(OR, 1.079; 95% CI, 1.025−1.135) and HDP (OR, 1.052; 95% CI, 1.042−1.061).

Results of multivariable logistic regression modeling are presented in Figure 3. It should be noted that aORs are in the zone of potential bias.[17] After adjusting for potential confounders, every 0.1 increase in EJI score remained weakly associated with APO, increasing the odds of APO by 1.4% (aOR, 1.014; 95% CI, 1.007−1.021). Individual clinical and sociodemographic factors were more strongly associated with the outcome of interest. Patients who were classified as either overweight (BMI, 25.0−29.9 kg/m$^2$) or class 1 obesity (BMI, 30.0−34.9 kg/m$^2$) at the time of delivery were at reduced risk for APOs compared with those who had a BMI that was either normal-range or underweight (reference group; BMI, <25.0 kg/m$^2$). Patients with class 2 obesity (BMI, 35.0−39.9 kg/m$^2$) or class 3 obesity (BMI, ≥40.0 kg/m$^2$) at the time of delivery were at increased risk for APOs compared with the reference group. Compared with non-Hispanic White patients, those belonging to all other race and ethnicity groups were at increased risk for APOs, with the highest risk observed among those who identified as Asian or Pacific Islander (aOR, 1.82; 95% CI, 1.73−1.91) and non-Hispanic Black (aOR, 1.69; 95% CI, 1.58−1.76). Weak associations with APOs (aOR, 1.1−1.5) were observed for AMA compared with non-AMA, for nulliparity compared with multiparity, and for public health insurance compared with private health insurance. Preferred language was not associated with APO.

The Supplemental Table shows the results of multivariable logistic regression evaluating the relationship between the social vulnerability module of EJI and (composite) APO, adjusting for confounding variables. The results were similar to those presented in Figure 3.

## Discussion

### Principal findings

In this retrospective cross-sectional study, we found that EJI score, which quantifies the social vulnerability and environmental burden of each census tract, is independently but weakly associated with APOs after adjusting for covariate factors. Of the adverse maternal and fetal outcomes included in the composite definition of APO, EJI was most strongly associated with stillbirth and HDP. Although both individual and neighborhood

**TABLE 2**
**Results of logistic regression evaluating the relationship between the Environmental Justice Index and individual conditions included in the adverse pregnancy outcome composite**

| Characteristic | Number (%) (n=65,273) | Unadjusted OR (95% CI) |
|---|---|---|
| APO, one or more | 24,545 (37.6) | 1.036 (1.029–1.042) |
| Hypertensive disorder of pregnancy | 8756 (13.4) | 1.052 (1.042–1.061) |
| Gestational diabetes | 7976 (12.2) | 1.006 (0.997–1.015) |
| Preterm birth | 5234 (8.0) | 1.029 (1.018–1.041) |
| Fetal growth restriction | 3956 (6.1) | 1.016 (1.003–1.029) |
| Low birthweight | 4563 (7.0) | 1.050 (1.037–1.062) |
| Small for gestational age newborn | 6455 (9.9) | 1.046 (1.035–1.057) |
| Placental abruption | 1072 (1.6) | 0.991 (0.968–1.015) |
| Stillbirth | 246 (0.4) | 1.079 (1.025–1.135) |

*APO*, adverse pregnancy outcome; *CI*, confidence interval; *OR*, odds ratio.

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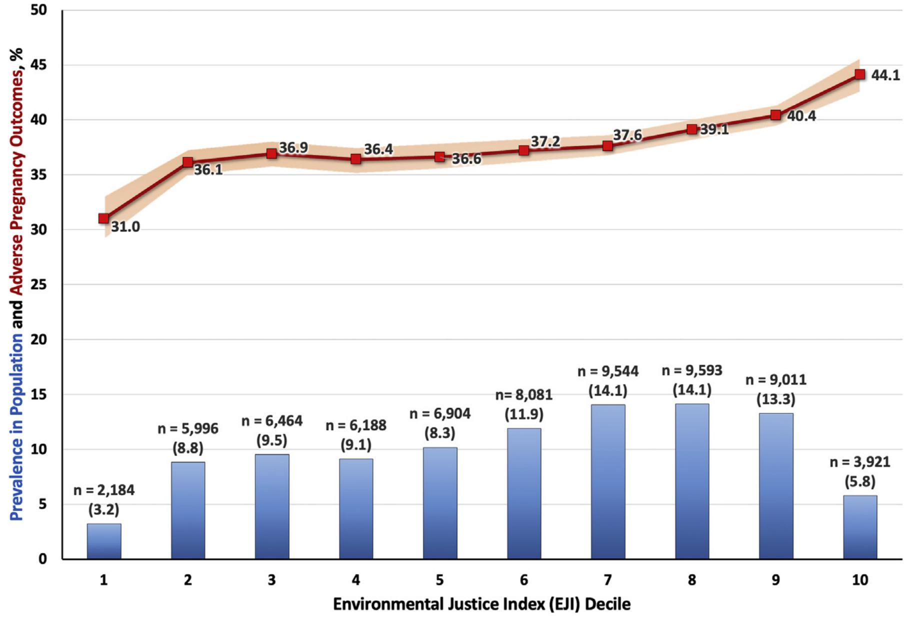
**FIGURE 2**
**Distribution of EJI scores and corresponding APOs**




*Bars represent the prevalence of each EJI decile in the cohort, and data points represent the APO rate, with shaded area indicating 95% confidence intervals.

*APO*, adverse pregnancy outcome; *EJI*, Environmental Justice Index.

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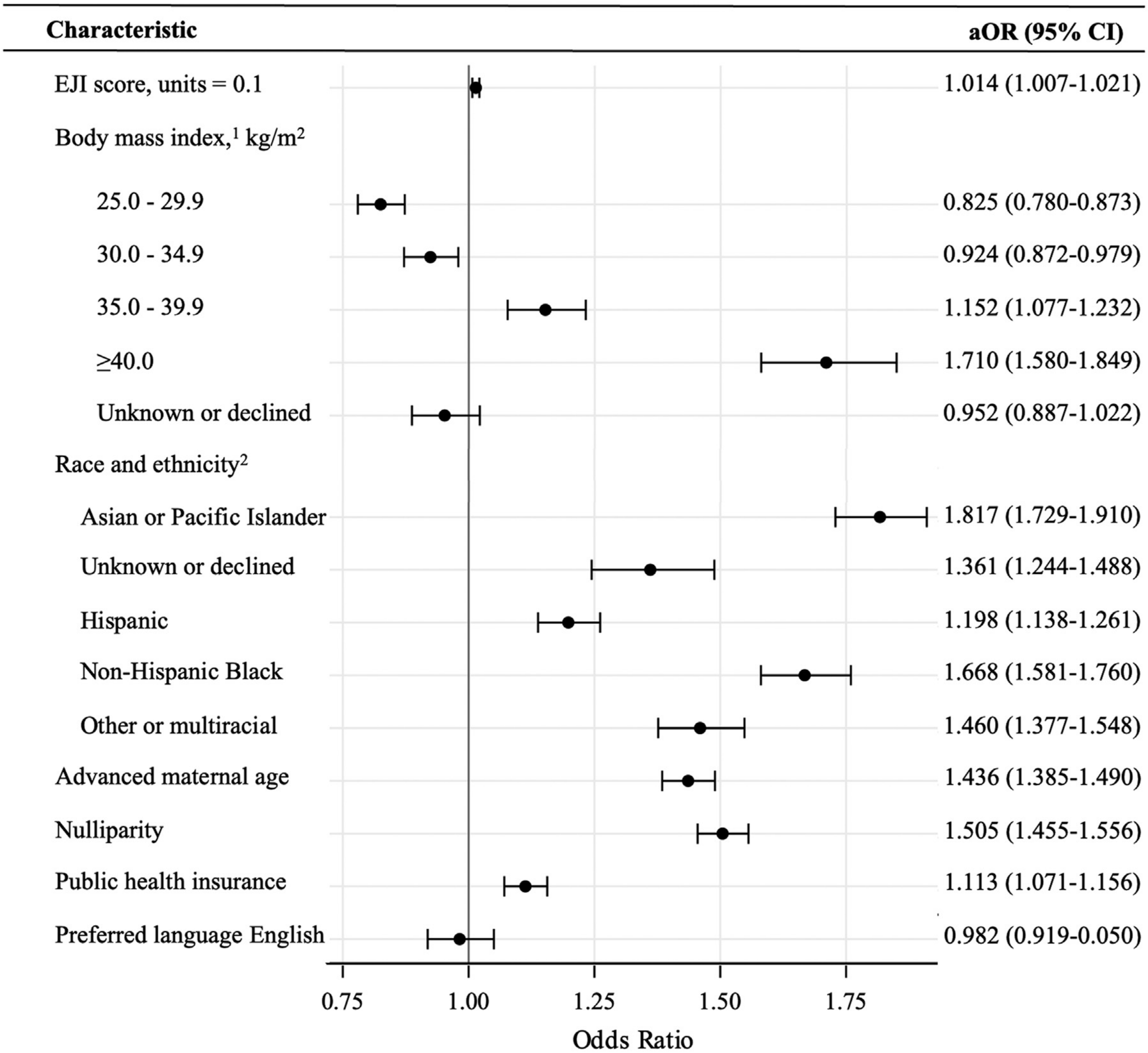
characteristics were associated with APOs, the strongest associations were observed with well-established clinical and social risk factors, including class 3 obesity and certain race and ethnicity groups, particularly Asian and Pacific Islander, and non-Hispanic Black.

## Results in the context of what is known

Although several investigators have studied the association between neighborhood characteristics and APOs, our study specifically evaluates the relationship between EJI score and APOs. To our knowledge, there is limited literature exploring the use of this geospatial analysis tool in analyzing pregnancy outcomes. Previous studies evaluating the relationship between the Social Vulnerability Index (SVI) and pregnancy outcomes have observed that pregnant patients living in high-SVI neighborhoods have an increased

**FIGURE 3**

**Multivariable logistic regression evaluating the relationship between EJI and APOs, adjusted for confounding variables**




[1]Body mass index reference group is <25 kg/m$^2$;

[2]Race and ethnicity reference group is non-Hispanic White.

*aOR*, adjusted odds ratio; *APO*, adverse pregnancy outcome; *CI*, confidence interval; *EJI*, Environmental Justice Index.

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likelihood of experiencing PTB before 37, 34, and 28 weeks of gestation, and their neonates have a higher likelihood of composite major neonatal morbidity.[14] Another study by Gulersen et al[15] evaluated the association between SVI and SMM. After adjusting for individual clinical and sociodemographic risk factors, SVI was not associated with SMM. Studies have also evaluated the relationship between the Area Deprivation Index and some individual APOs, noting increased risk for diabetes[18] and abnormal birthweights at both extremes in neighborhoods with higher area deprivation.[19]

Our finding that patients with higher EJI scores are more likely to experience APOs is consistent with previous literature demonstrating that environmental exposures[20–22] and neighborhood socioeconomic conditions[23–26] both negatively affect pregnancy outcomes. Poor-quality built environments are harmful to pregnancy. Specifically, air pollution, fine particulate matter, and contaminated drinking water have been associated with APOs such as LBW, FGR, HDP, PTB, and stillbirth.[22,27–32] In some studies, the exposures are directly measured, and in many others, they have been inferred on the basis of proximity to a potential emission source (ie, highway, power plant, hazardous waste site). Neighborhood socioeconomic deprivation also affects pregnancy outcomes. Areas strongly affected by poverty, violent crime, and racial and ethnic segregation are at increased risk for PTB and LBW.[33] For pregnant persons living in disadvantaged neighborhoods (ie, food and job insecurity, reduced access to healthcare, lack of transportation, inadequate schooling), maternal psychological stress has been shown to be associated with PTB, HDP, and LBW.[34−36] The exact causal pathways for these findings must be better elucidated. One often-proposed physiological mechanism for the association between maternal stress and APOs are high maternal cortisol levels and inflammatory markers; nevertheless, previous studies have produced inconsistent findings.[37−41]

Importantly, some authors have suggested that the combination of environmental and social disadvantage may have a synergistic effect, imposing a greater burden on these communities than either component in isolation.[42] Thus, EJI may help to identify the neighborhoods at highest risk for APOs and long-term CVD risk.

## Clinical implications

According to our results, the EJI score has several clinically useful applications for pregnancy. It provides the opportunity for targeted health interventions by identifying specific neighborhoods with increased risk for APOs that may benefit from allocation of additional resources. When the EJI tool is linked to local (individual) clinical data, it facilitates assessment of health disparities among pregnant persons and may help guide policy development to promote health equity. Specifically, efforts should be made to ensure access to prenatal care services in the most vulnerable communities. Finally, EJI can assist healthcare providers in developing targeted health education and outreach campaigns by tailoring their messaging and communication strategies to address specific, local social or environmental concerns affecting pregnancy.

## Research implications

Further investigation of how the built and social environments affect pregnancy outcomes is necessary. There is a critical need for rigorously designed prospective studies that capture the total environment (social, built, natural), total patient (clinical, demographic, socioeconomic, genetic, behavioral), and well-defined, specific pregnancy outcomes. We must continue to identify not only epidemiologic associations but also the underlying mechanisms that contribute to various APOs. Changes in oxidative stress and inflammation may contribute to placental dysfunction in some APOs, but current data are limited.[43] It should be determined whether patients living in neighborhoods with higher EJI scores have alterations in these markers. More broadly, there is an opportunity to use the EJI tool to evaluate its association with other pregnancy outcomes.

## Strengths and limitations

Our study has several strengths. All included hospital sites use a single, shared electronic medical record system, which allows for uniformity of data collection. The patient population is diverse and resides in both urban and suburban communities across a large geographic region. The area-level units used in our geospatial analysis were census tracts, which are relatively small areas with well-defined boundaries, and typically contain <8000 people. For comparison, ZIP Codes may contain >100,000 residents in heavily populated urban areas. Therefore, data at the census tract level should better reflect local conditions than ZIP Code−associated data. Furthermore, EJI data are publicly available, easily accessible, and can be applied to other regions across the United States.

Our study also has several limitations, including its retrospective design, which only allows us to demonstrate associations between exposure and outcome, not causal relationships. The primary outcome was a composite of several different conditions, some of which are identified only by administrative data. Our findings may not be generalizable to geographic areas outside of New York City and Long Island. Notably, we did not evaluate individual (patient-level) socioeconomic indicators such as income, employment, and educational attainment because these data were not consistently available. Thus, we cannot necessarily know whether certain patients residing in more disadvantaged areas are financially better off than their neighborhood characteristics would suggest. In scenarios such as this, what is true for the group may not necessarily be true for the individual; failure to acknowledge this is referred to as ecological fallacy.

## Conclusions

EJI score is independently but weakly associated with APOs. Adverse maternal and fetal outcomes are more strongly associated with individual social and clinical risk factors compared with neighborhood characteristics. However, risk is further increased by neighborhood social vulnerability and environmental burden. A better understanding of geospatial determinants of APOs combined with public health efforts to reduce APO risk factors may allow for improved pregnancy outcomes. ■

## CRediT authorship contribution statement

**Jaclyn Del Pozzo:** Investigation, Writing − original draft, Writing − review & editing. **Insaf Kouba:** Investigation, Methodology, Writing − review & editing. **Alejandro Alvarez:** Data curation, Formal analysis. **Tadhg O'Sullivan-Bakshi:** Conceptualization, Investigation. **Kaveri Krishnamoorthy:** Conceptualization, Investigation. **Matthew J. Blitz:** Investigation, Methodology, Resources, Supervision, Writing − review & editing.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xagr.2024.100330.

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